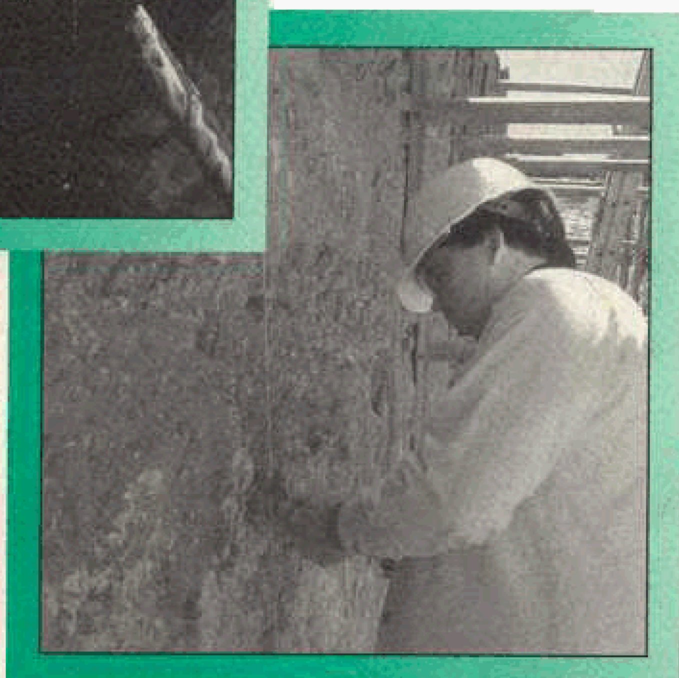
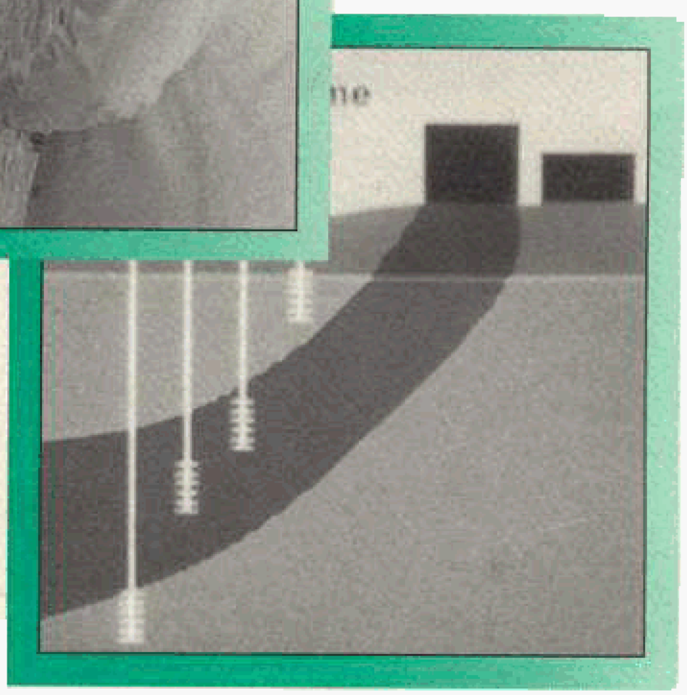
Guidelines for Hydrogeologic Characterization of Hazardous Substance Release Sites

Volume 2: Project Management Manual

Appendix A Case History

Appendix B Sources of Information





State of California
Environmental Protection Agency

APPENDIX A: CASE HISTORIES

The following case histories are presented to illustrate how the hydrogeologic characterization process and the methods presented herein can be used to successfully characterize site-specific hydrogeology. To demonstrate the flexibility of the process and its applicability to sites of different size and complexity, three case histories are presented. The first is a site where initial screening indicated potential ground water contamination, but was subsequently ruled out by a limited investigation. The second is a site with simple geology and contamination limited to a single chemical. Finally, a site with complex geology, multiple ground water contaminants and multiple source areas is presented.

A.1 No Further Action Site

Whenever No Further Action is proposed as the remedial alternative for a site, that proposal should be supported by a sound assessment of the potential for migration of contaminants and their ultimate fate. For ground water (as with any other medium), No Further Action can only be supported when one or more of the following criteria exist:

- it can be demonstrated that contaminants are unlikely to migrate and will remain localized at their source,
- if contaminants can or did migrate, that there is no route for exposure by human or other environmental receptors,
- if contaminants can or did migrate, and a potential route for exposure exists, such exposure is or would be at concentrations insignificant to adversely affect human health or the environment.

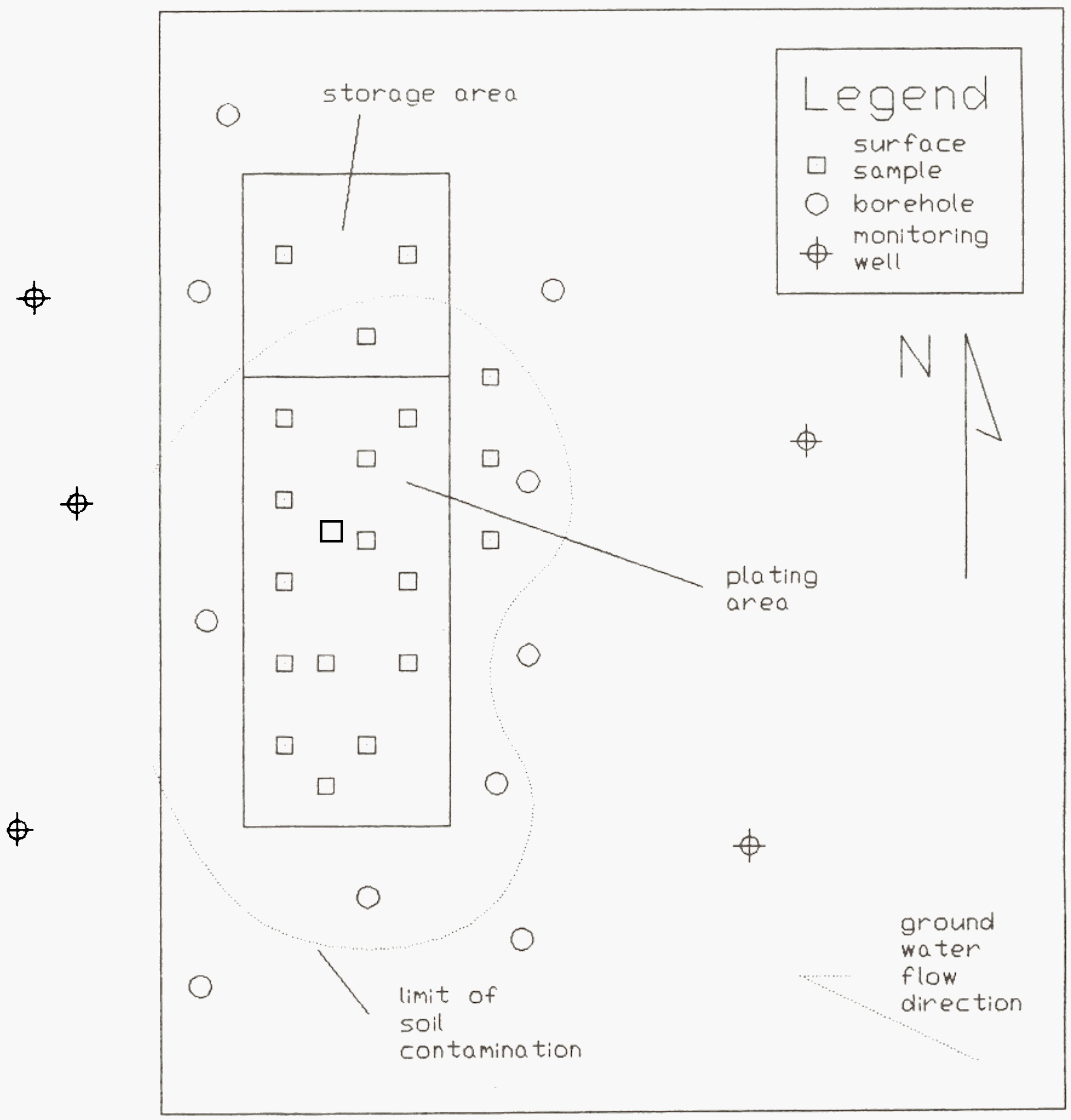
The following hypothetical case study, based on an actual site investigation, is presented to illustrate one scenario where the No Further Action alternative for ground water may be a viable solution.

Introduction

A zinc galvanizing facility operated in northern California from 1968 until 1982. In February of 1982, the facility was closed and dismantled. Figure A.1 provides a plan view of the site and the original locations of dip tanks and galvanizing kettles. Onsite soil contamination from zinc and acid solution spills was documented during preliminary sampling in 1983. Within the contaminated area, zinc was detected to 14,000 ppm, lead was detected to 2,344 ppm, and soil pH ranged from 1 to 3.3.

The site came to the attention of the DTSC in 1985, with the submittal of a summary report, site investigation report and proposed remedial action. Based on DTSC review, the report was judged substandard and was returned for amendment. In 1987, after repeated efforts to persuade the RP's to pursue investigation and cleanup activities, DTSC issued a Remedial Action Order. Shortly thereafter, after changing consultants, the RP's submitted a workplan to complete an RI/FS. The subsequent investigation further delineated the lateral and vertical extent of lead and zinc contamination. Ground water monitoring wells were also installed, to verify that ground water was not impacted by contamination in the vadose zone.

Figure A.1. Layout of site representing the no further action case history. Drawing is not to scale.



In 1989, the RP's completed the remedial investigation to the satisfaction of the DTSC. In 1990 the feasibility study was completed, and onsite soil treatment and capping were selected as remedial alternatives.

Geology

The site is located in the Great Valley geomorphic province of California, on the ancestral delta of the San Joaquin River. Fluvial deposition in the area occurred by river meandering. The resulting topography is nearly level, forming a broad plain area. The soils at the site consisted primarily of silt and clayey silt with minor sand layers to a depth of 25 feet. Below this, the soil is primarily silty sand to the maximum depth explored, 38 feet below ground surface (bgs).

Hydrogeology

The major source of ground water in the area occurs in discontinuous deposits of sand, gravel, clay, and silt. A regionally extensive clay layer exists near the top of this water-bearing zone.

Near the site, historical drilling and geophysical logs indicate the upper 250 feet of sediments are predominantly silt and clay, with several discontinuous beds of sand and silty sand up to 15 feet thick. A sand and gravel bed, 10 to 30 feet thick, occurs consistently from 225 to 250 feet bgs. This zone and deeper zones are referred to as the "deep aquifer". The water-bearing zone above this is termed the "shallow aquifer". Permeable layers within arbitrarily-defined intervals in the shallow aquifer are designated as A, B, C, and D zones. The A zone generally occurs between 30 and 40 feet bgs. Permeable sands between 30 and 60 feet are designated as the B zone. The C zone contains sand layers between 100 and 150 feet bgs, and the D zone consists of sand layers between 160 and 190 feet below ground surface.

Investigation Results

Characterization of ground water at the site was limited to the A zone of the shallow aquifer, where ground water was encountered at 22 feet below ground surface. Seven borings were advanced into the A zone, to a maximum depth of 38 feet below ground surface; 5 of the borings were completed as ground water monitoring wells, each screened from 18 to 38 feet bgs (a 20 foot interval), to account for seasonal elevation changes in the water table.

Information gathered during project scoping indicated the direction of regional ground water flow was southeast. Therefore, three monitoring wells were initially planned: one upgradient and two downgradient of the site. Piezometric data from these initial wells revealed that ground water at the site was approximately 22 feet below ground surface, flowing northwest under the influence of a small horizontal gradient (opposite of the predicted direction). Based on that information, two additional wells were installed downgradient of the site. Ground water samples collected from all five wells detected neither lead nor zinc, indicating that the metals were attenuated within the vadose zone.

Extensive sampling of the vadose zone established that soil contamination at the site was laterally localized and within 10 feet of the surface. Depth of contamination was greatest in areas of low pH (<3), where solubility of the metals was enhanced. Regular sampling of the monitoring wells showed ground water pH was consistently near neutral, and neither lead nor zinc were detected in ground water.

An assessment of fate and transport was conducted for zinc and lead. The results concluded that mobility of these metals in the vadose zone and ground water was highly dependent on acidic conditions, which were limited to the vadose zone at the site. When these conditions did not exist, the metals would not readily migrate in either medium.

Based on this information, proposed remedial activities were limited to soil. Approximately 1,500 cubic yards of contaminated soil were excavated, treated and placed in an onsite trench. An asphalt and concrete cap was then constructed over the site to minimize infiltration of precipitation. No further action was required for ground water.

The remediation was certified by DTSC after a Deed Restriction and Operation and Maintenance Agreement were filed. The Deed Restriction restricts use of the property to manufacturing. The Operation and Maintenance Agreement requires maintenance of the asphalt and concrete cap over the stabilized soil, continued ground water monitoring and a five year adequacy review for the remedial measures.

A.2 Simple Site

This section presents a case study of a fairly simple hazardous waste site that required further characterization (and remediation) beyond a preliminary investigation or Preliminary Endangerment Assessment. Although based on an actual case, the text presented here does not reveal the names of potential responsible parties or any consulting firms involved in the investigation.

Background

The site is a small ranch located in an agricultural area of the San Joaquin Valley, California (Figure A.2). In 1981, the site owners contracted with a local sand and gravel company to have a swampy area filled with demolition material. Approximately 30,000 cubic yards of debris were buried at the site including approximately 1,500 cubic yards of chromium-contaminated furnace bricks from a glass company. The bricks had been used to line firing kilns, and were contaminated with chromium salts used to provide a green tint to glass. Although originally the water table was below the base of the landfill excavation, the water table rose significantly during the winter of 1982-83 as a result of unusually high rainfall. Consequently, ground water came into direct contact with the chromium-contaminated bricks and stayed in contact for several months, leaching chromium into the ground water. Ground water at the site became contaminated with hexavalent chromium, resulting in a distinct plume that spread over time.

In early 1983, the Department indirectly became aware of the site through a complaint from some nearby city residents. The complaint reported a yellow powder leaching from bricks used in recently built patios and driveways, dying vegetation adjacent to these new structures, and sick pets. Department staff sampled the bricks, and confirmed that the bricks were significantly contaminated with hexavalent chromium. The Department then learned that the building contractor had procured the bricks from the site.

Regional geology and hydrogeology

The site is located in the Great Valley Geomorphic Province. The site lies within a large area of low plains and alluvial fans, bounded by dissected uplands to the east and river flood plains to the north, south and west. The study area is within 5 miles of four significant surface water bodies.

In the vicinity of the site, approximately 10,000 feet of undeformed, mostly sedimentary rocks and unconsolidated sediments overlie a basement complex of metamorphic and igneous rocks. The main unconsolidated sediments constituting the regional hydrogeologic system are discussed briefly below.

Older alluvial deposits consisting of poorly sorted gravel, sand, silt, and clay occur at a depth of about 250 feet below ground surface (bgs), and have a maximum thickness of 450 feet. Fine-grained, Pleistocene lacustrine deposits overlie the older alluvial deposits. These deposits include a significant clay unit known as the "E clay". The lacustrine deposits attain a maximum thickness of about 120 feet, and in the vicinity of the study area, the E clay occurs at a depth of about 130 feet bgs. The youngest strata comprise Quaternary clastic deposits, mainly of fluvial origin. These sediments include river channel deposits of sand and gravel, and flood-plain deposits of sand and silt. This series attains a thickness of about 115 feet.

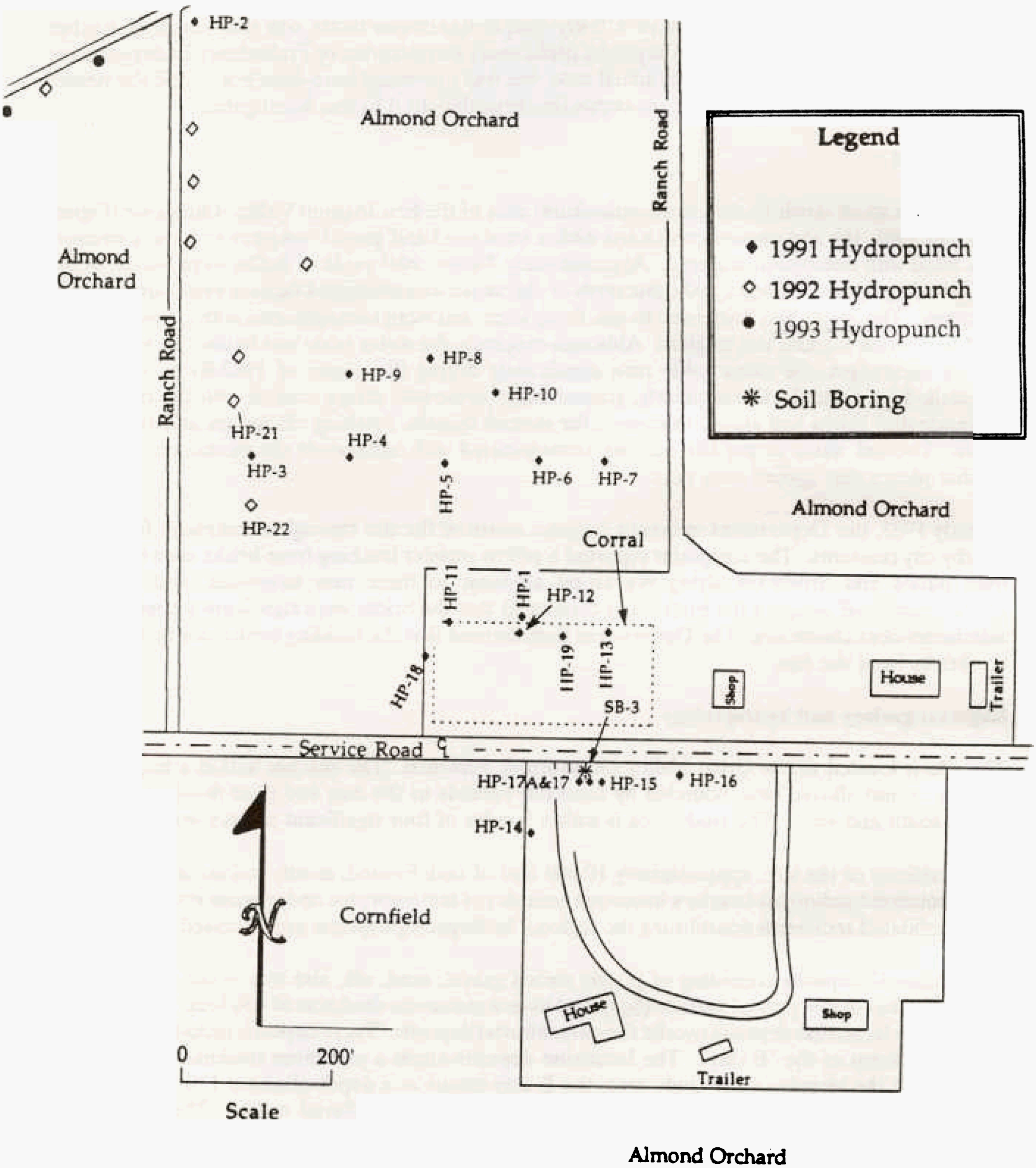


Figure A.2. Layout of the site representing the simple case history. Use of trade names does not constitute endorsement.

On a regional scale, the unconsolidated sequence comprises two aquifers (consisting of older and younger alluvial deposits) and an intervening aquitard (made up of Pleistocene lacustrine deposits). The lower regional aquifer, consisting of older alluvial deposits, is up to 450 feet thick. The upper regional aquifer, comprised of younger alluvial deposits, is up to 130 feet thick. The intervening regional aquitard is up to 120 feet thick. These thicknesses are approximate and are applicable only on a regional scale.

Ground water generally flows westward, away from the main recharge zone in the foothills and mountains of the Sierra Nevada Range. However, local departures from this regional trend exist. In the vicinity of the study area, shallow ground water flows northwesterly at approximately 140 feet/year (0.384 feet/day).

Shallow ground water (near the water table) is slightly saline, with specific conductance in the range of 2500 to 3500 millimhos per centimeter (mmhos/cm), which is above the recommended maximum for drinking water. In contrast, the lower water-bearing zone carries water with a specific conductance typically less than 900 mmhos/cm.

Site specific geology and hydrogeology

Sedimentary deposits in the vicinity of the site consist entirely of unconsolidated clastic materials, ranging in texture from gravel to clay. Six main stratigraphic units were identified within 150 feet of the surface, consisting of the following (from top to bottom):

> Upper sand unit This unit consists mainly of poorly sorted sand, with variable amounts of silt and clay. It extends from the surface to a depth of 30 to 35 feet bgs throughout most of the study area, although locally it is over 50 feet thick. Distinct lenses of clay or silt, less than two feet thick, occur between 20 and 30 feet bgs.
>
> Upper silt/clay unit This unit consists of interbedded silt and clay and subordinate sand, and varies in thickness from 10 to 30 feet. Spontaneous-potential and resistivity logs corroborate the thinly interbedded character of this unit.
>
> Lower sand unit This unit consists primarily of well-sorted, medium- to very coarse-grained quartz sand, with subordinate interbeds of silt and clay. The unit averages 45 feet in thickness. Geophysical logs indicate that the sand layers have very high resistivity, and the silt layers have moderately low resistivity. This is consistent with the observation (from continuous cores) that the sands are clay-poor and the silts are moderately clay-rich. The resistivity response suggests that the sand strata are highly permeable and contain fresh ground water.
>
> Lower silt/clay unit This unit is similar to the upper silt/clay unit in its composition and layering character. It is a thin unit, varying in thickness from 4 to 7 feet. This unit appears to exist only in the southwest half of the site.
>
> Gravel unit This unit consists of poorly sorted pebbles and larger gravels in a matrix of poorly sorted sand and silt. Locally, it contains some thin clay layers, and typically includes a layer of well-sorted, fine- to medium-grained sand at its top. The gravel unit is laterally discontinuous and occurs at variable depths. The unit varies in thickness from 4 to 14 feet.

Basal clay unit This unit is the lowest stratigraphic unit investigated. It is a dense, gray clay at least 30 feet thick. A survey of private water well boring logs from the area indicates that the basal clay unit is laterally continuous. Depth to the top of the unit varies laterally, from about 115 to 140 feet bgs. Available resistivity logs indicate uniformly low resistivity values for the basal clay unit. The basal clay unit is equivalent to the regionally defined "E clay".

Depth to ground water in the study area currently varies from 23 to 32 feet bgs. However, in the winter of 1982-83, when contamination was first introduced to ground water, the water table was as shallow as 12 feet bgs, largely because of greater than average rainfall.

In the study area, ground water does not flow uniformly through the upper aquifer. Locally, three stratigraphic units act as barriers to ground water flow. The most important and widespread of these is the basal clay unit. Because of its lateral continuity and apparently very low hydraulic conductivity, this unit forms an effective aquitard that strongly restricts downward movement of ground water, even on a regional scale. Thus, the hydrogeologic system of interest in this study is limited to strata above a depth of approximately 115 to 140 feet bgs.

The lower silt/clay unit impedes vertical flow of ground water in the southwestern half of the study area, where it acts as a leaky aquitard. The upper silt/clay unit is the other leaky confining layer in the system. It appears to be continuous across the study area, but like the lower silt/clay unit, is not a completely effective aquitard.

Scoping activities

In April 1983, the Department asked the site owner to provide a plan for removal of the bricks. At that point, the original scope of investigation of the site was to assess the affect of the refractory bricks on soil and ground water. This initial investigation, conducted in October 1983, determined that (1) chromium occurs in very low concentrations in refractory bricks representative of those that had been buried; (2) in soil samples from depths as great as 35 feet, concentrations of trivalent chromium were low, and hexavalent chromium was not detected; (3) in ground water samples from three newly installed monitoring wells and two nearby private wells, trivalent chromium was present in low concentrations, and hexavalent chromium was not detected. Based on these initial results, the threat to ground water seemed to be slight, but continued monitoring of the monitoring wells was recommended.

In January 1985, fifteen months after the three monitoring wells were installed, hexavalent chromium was detected in ground water at levels exceeding the drinking water standard. The bricks were removed in 1986, and after chromium concentrations continued to be low throughout 1985 and 1986, a February 1987 report concluded that the site had been completely remediated. However, the Department did not agree with that assessment and required additional investigation of the site.

Selection of study approach

Subsequent phases of monitoring well installation and in-situ ground water sampling investigations shows that the areal scope of the investigation grew with the lengthening chromium plume. The first monitoring wells were near the landfill and later wells were installed down-gradient. After the plume had been adequately characterized and a feasibility study had been performed, a remedial action plan was developed.

The chosen remedial action involved extraction and treatment of ground water at a permanently installed facility on site. However, as a consequence of the rapid migration of the chromium plume, by the time the ground water extraction system was in place, it was no longer capable of capturing the leading edge of the plume. Consequently, further down-gradient characterization and modification of the extraction/treatment system was required.

Remedial Investigation Summary

Reconnaissance studies

Early reconnaissance studies were designed to delineate the extent of the bricks within the landfill and to provide initial characterization of the surrounding soil. In early 1986, sixteen trenches, up to 16 feet deep, were excavated in and around the landfill area. Six test pits were also dug. Finally, three shallow monitoring wells were installed. The locations of these features are shown in Figure A.3. Soil samples were collected and analyzed in all cases. This early phase of study provided effective delineation of the bricks, characterization of the shallow lithology, soil samples for determining the extent of chromium contamination, and the means to begin monitoring shallow ground water.

Rapid field evaluation methods

The only rapid field evaluation method ever employed in the study area was in situ ground water sampling. Using this system, lithologic data were gathered while boring down to one or more targets below the water table. At these target depths, discrete samples of ground water were collected for analysis. A total of 31 separate locations were investigated using this method (the locations are shown in Figure A.2).

In-situ ground water sampling investigations were effective in constraining the lateral and vertical extent of the chromium plume, at the time of sampling. Although depth-discrete in situ ground water samples represent only one point in time, they were valuable in helping to specify the locations of new monitoring wells.

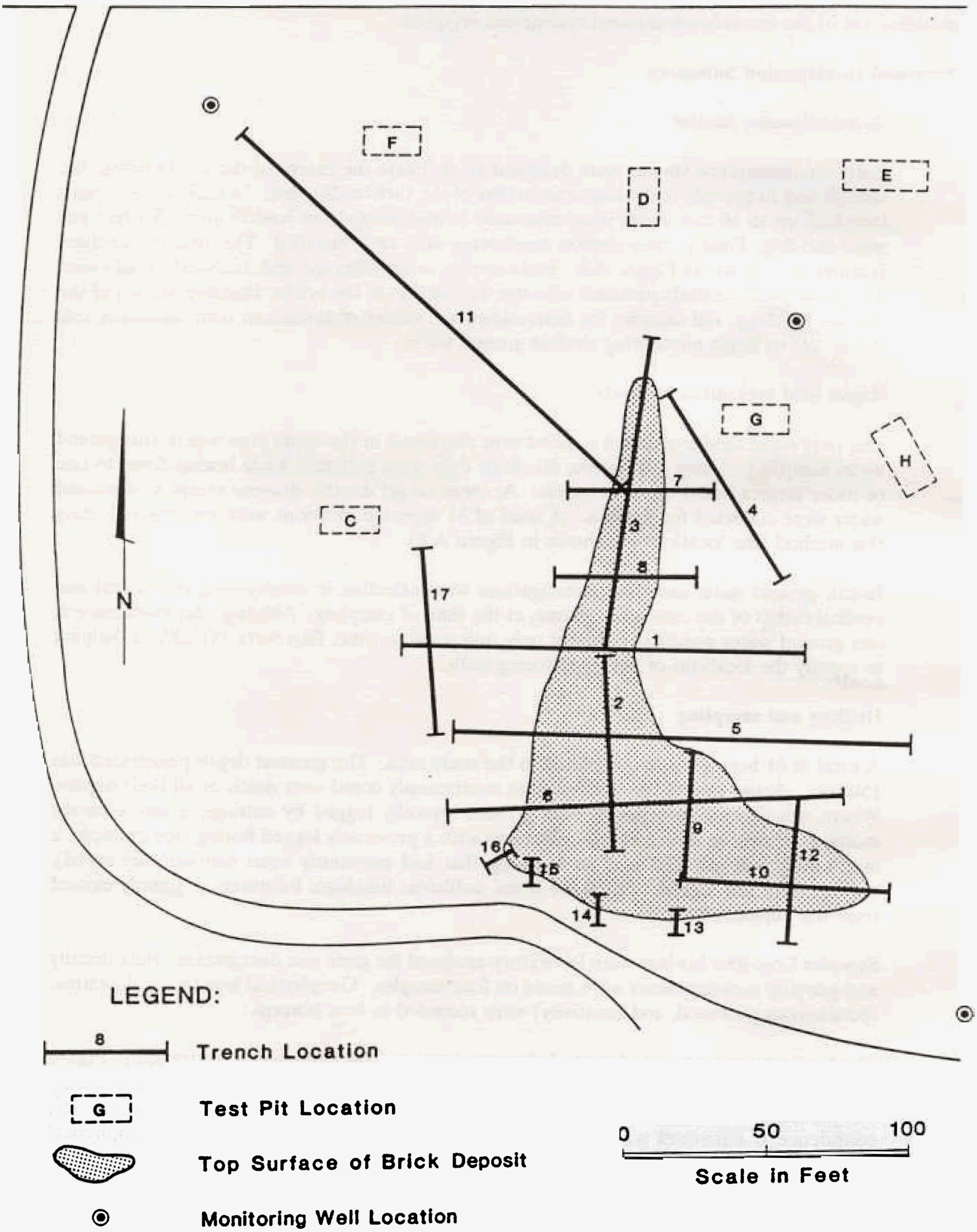
Drilling and sampling

A total of 61 borings were completed in the study area. The greatest depth penetrated was 150 feet. About half of the borings were continuously cored over much or all their depths. Where not continuously cored, borings were typically logged by cuttings, a less accurate method. However, where nearly coincident with a previously logged boring (for example, a monitoring well installed next to a boring that had previously been continuously cored), borings were not logged. For these holes, sufficient lithologic information already existed from the adjacent borings.

Samples from four borings were laboratory-analyzed for grain size distribution. Bulk density and porosity measurements were made on four samples. Geophysical logs (natural gamma, spontaneous potential, and resistivity) were recorded in four borings.

The boring program resulted in good characterization of the study area's stratigraphy. Figure A.4 is a representative stratigraphic cross section through the study area. Continuous coring was performed in enough borings to provide confidence in the geologic characterization. The confidence is enhanced where borings were also geophysically logged. The geophysical responses were generally in good agreement with the corresponding core.

Figure A.3. Locations of reconnaissance activities conducted at the simple site.



There are several occurrences of adjacent borings in which one was continuously cored and the other logged only by cuttings. In these cases, it is apparent that borings logged by cuttings provide only a gross generalization of the stratigraphy. It is clear that cuttings alone do not provide sufficiently detailed information. Where cuttings are not corroborated by cores, the resulting lithologic information should be supplemented by geophysical logs.

Ground water monitoring

Since 1985 (following initial sampling in 1983), sampling and analysis has been on a quarterly basis. In the early part of the investigation, analytical results from the first three monitoring wells typically ranged from non-detect to just above the MCL for chromium, indicating that shallow ground water (upper sand unit) was probably not significantly contaminated. However, because the vertical component of the hydraulic gradient was not initially known, further hydrogeologic characterization was necessary to investigate vertical ground water flow and confirm the extent of chromium contamination. In December 1987, three more monitoring wells were constructed, including a well completed in the lower sand unit.

When water samples from this deeper zone proved to be significantly contaminated with chromium in January 1988, it became clear that the ground water contamination problem was larger than had been previously envisioned. Eventually, a total of 28 monitoring wells were installed (see Figure A.5), including seven monitoring well clusters to assess the vertical component of ground water flow and contaminant migration.

The monitoring well network provided good characterization of the chromium plume (Figure A.6), and also provided good monitoring of ground water elevations. The well clusters demonstrated that vertical gradients were a significant factor in contaminant migration.

Aquifer testing

As part of the initial hydrogeological assessment in 1983, slug tests were done on each of the first three monitoring wells. In addition, slug tests were performed to evaluate hydraulic properties of the upper silt/clay unit.

Slug test results indicated that hydraulic conductivity of the shallow aquifer (the upper sand unit) in the vicinity of the former landfill varies between 8.5 and 19.8 feet per day. Hydraulic conductivity in the upper silt/clay unit ranges between 3.2 and 6.1 feet per day.

An aquifer evaluation study was performed in early 1989. The study was designed to (1) assess the production capacity of the upper and lower aquifers; (2) assess the change in chromium concentration as a function of volume of water pumped; and (3) assess the effect on the upper aquifer of pumping in the lower aquifer. Monitoring wells were successively pumped, and water elevation was observed in all other monitoring wells. Although this was an innovative study, it was not strictly an aquifer test in the usual sense.

The 1989 aquifer evaluation study provided a qualitative assessment of the hydrogeologic system. While pumping from the lower sand unit, noticeable drawdown was observed in the upper sand unit, indicating a hydraulic connection between the two water-bearing zones. Additionally, chromium concentration dropped dramatically during pumping.

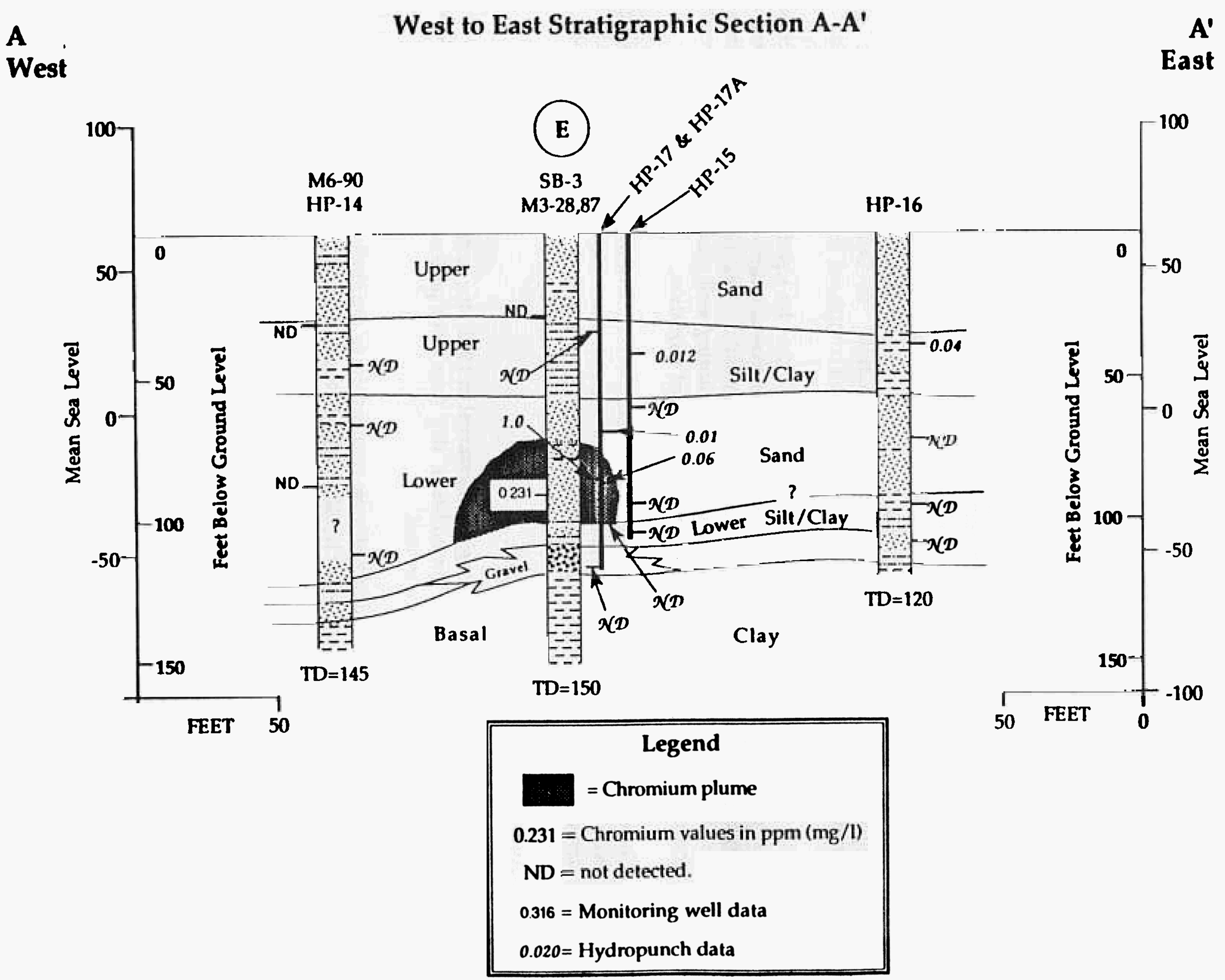


Figure A.4. Representative cross-section for the simple site.

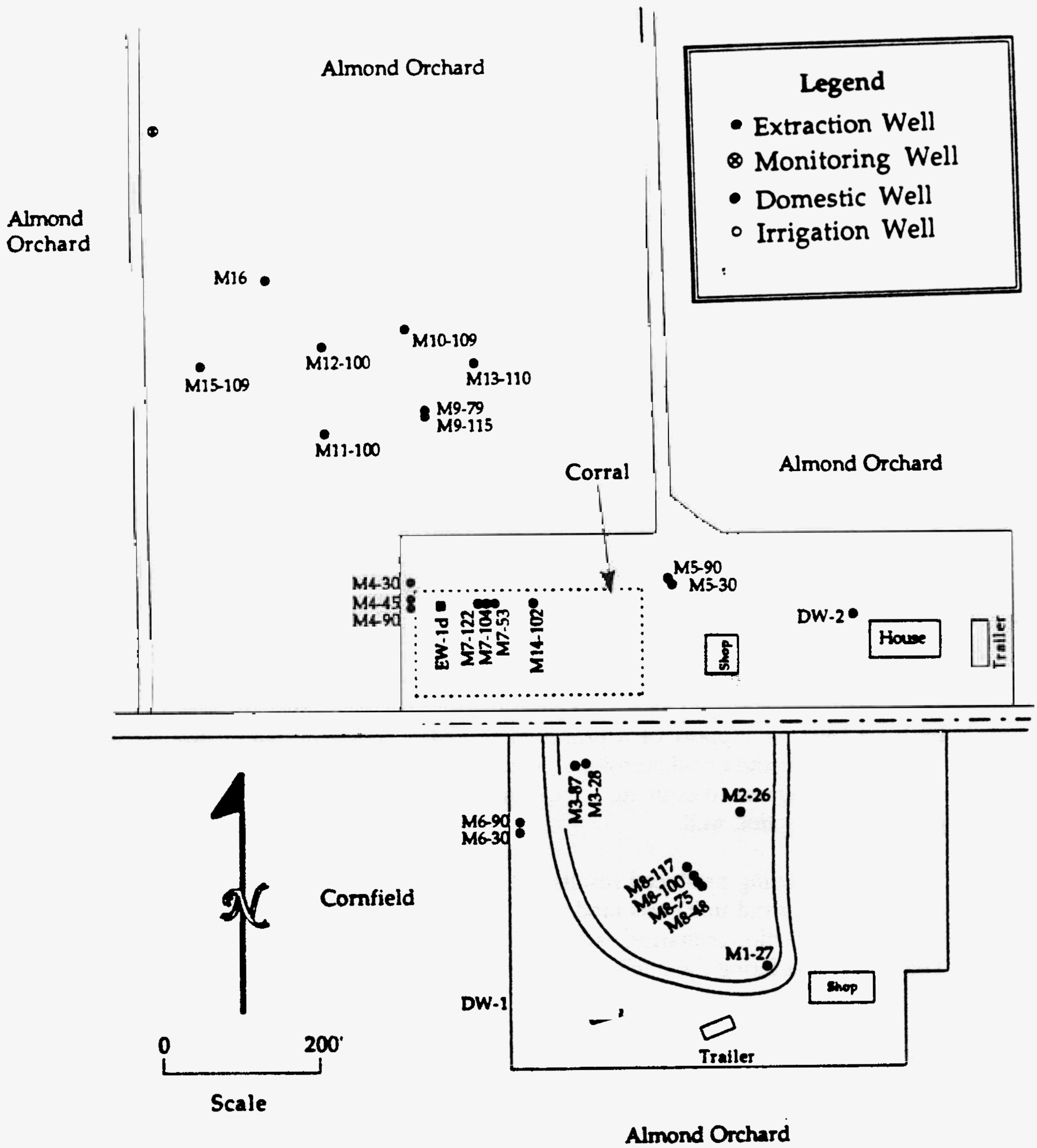


Figure A.5. Monitoring well locations at the simple site.

In 1992, another set of aquifer tests was conducted. Preparatory to those tests, in December 1991 a step drawdown test was performed to evaluate the capacity of extraction well EW-1D, which had been constructed in that same month. The step drawdown test of EW-1D employed 11 observation wells. The pumped well and all of the observation wells are screened in the lower sand unit. After measuring all water levels prior to pumping, EW-1D was pumped at increasing rates in regular time increments.

In March and April 1992, a constant discharge aquifer test was performed. The lower aquifer (lower sand unit) was stressed by pumping well EW-1D at a high rate (determined from the step drawdown test) for three days. The extraction well and 8 observation wells were continuously monitored during the test using a data logger. Water levels in 16 other monitoring wells were measured manually at frequent intervals.

Analysis of the drawdown curves from the 1992 constant-rate aquifer test, combined with existing knowledge of the local geology, indicated that the lower sand unit acts as a leaky-confined aquifer. The results indicate that, in the vicinity of EW-1D, hydraulic conductivity of the lower sand unit ranges from 9 to 118 feet/day, averaging about 39 feet/day. Drawdown results indicate that pumping in the lower sand unit induces a hydraulic gradient (and presumably ground water flow) from both the gravel and upper sand units to the lower sand unit.

Ground water modeling

Capture zone modeling, conducted in 1990, indicated that the chromium plume could be effectively captured by implementing one of two alternative ground water extraction schemes. Alternative 1 involved extracting water near the former landfill, by pumping two upper sand unit wells and two lower sand unit wells. Alternative 2 involved extracting water near the orchard area, by pumping three upper sand unit wells and three lower sand unit wells.

In June 1992, in support of a proposed remedial action design, computer modeling was conducted using the two-dimensional semi-analytical model RESSQC. As in 1990, the intent of the modeling was to estimate the capture zones of three existing wells and one additional proposed extraction well.

The 1992 modeling produced results similar to the 1990 results. However, only the lower aquifer (lower sand unit) was modeled. The main results of the 1992 modeling were four candidate extraction scenarios, each of which would effectively capture the chromium plume. The scenario offering the quickest remediation time involved four extraction wells and four recharge wells.

Conclusions

Numerous hazardous waste sites in California are situated within stratigraphic and hydrogeologic environments similar to this simple site. As such, this case study (with both its successes and pitfalls) serves well as a representative scenario. The main principles that can be learned from this site are summarized below.

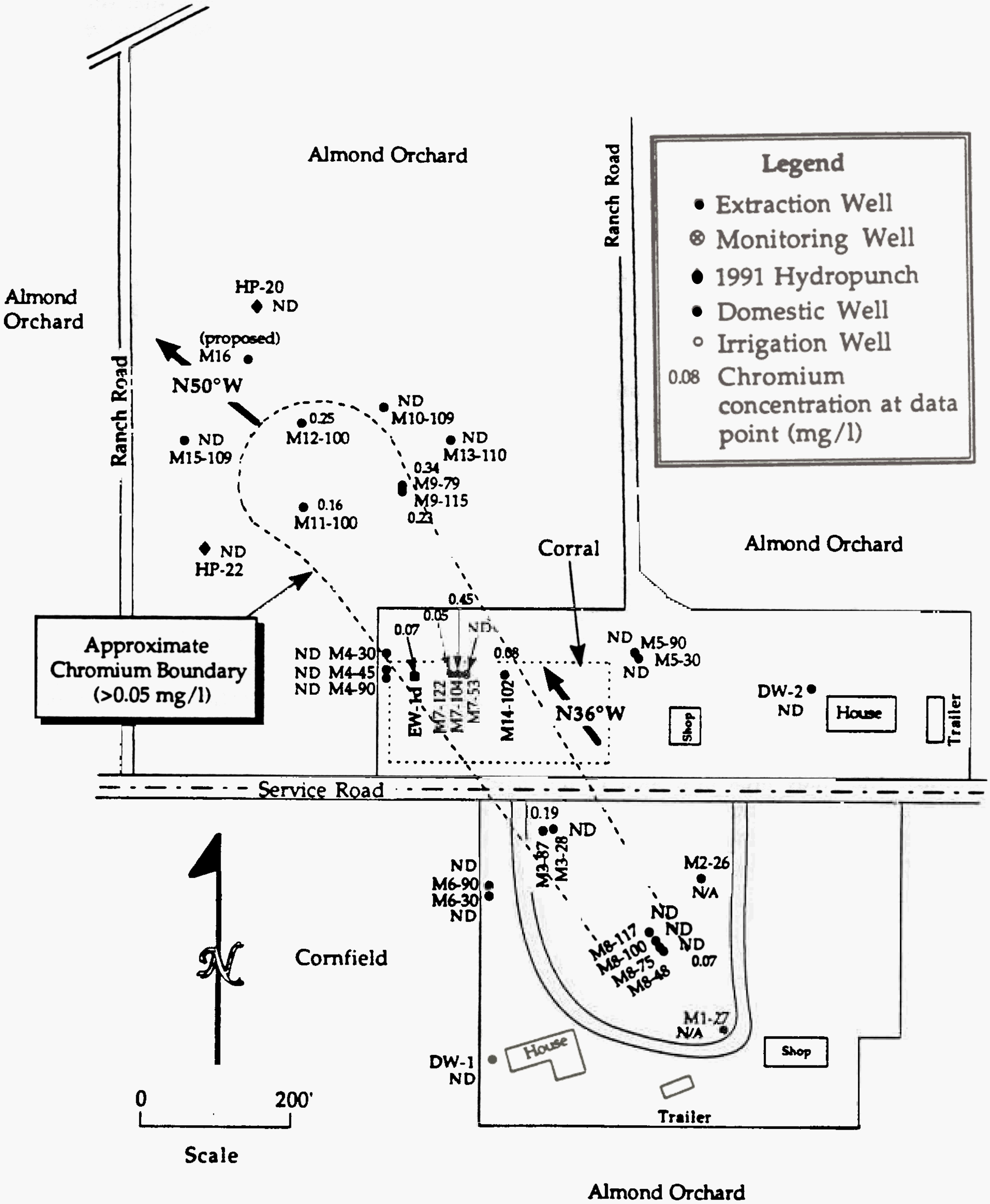


Figure A.6. Extent of chromium contamination in ground water at the simple site.

Initial scoping of the contamination problem is frequently inadequate. One of the basic reasons that this site was considered to be completely remediated at a fairly early stage was that vertical flow of ground water had not been evaluated. A significant time interval elapsed (four years) before monitoring of deeper ground water was initiated; consequently, the chromium plume grew significantly, unchecked. Unfortunately, vertical movement of ground water is still frequently under-appreciated.

On the positive side, once it was known that a plume did exist, the investigation of the stratigraphy and hydrogeology proceeded in a logical manner. As such, the data needs of the feasibility study were adequately anticipated during the remedial investigation.

- The series of in situ ground water monitoring investigations helped delimit the chromium plume, providing a rational basis for efficiently locating additional monitoring wells (not only their horizontal locations, but also their screened intervals).

- Soil borings provided valuable lithologic data necessary for assessing geology and hydrogeology. Because a high percentage of the total borings was logged by continuous coring, there is a correspondingly high confidence that the lithologic and hydrostratigraphic framework was accurately established.

- In anticipation of a remedial design involving extraction and treatment of ground water, adequate aquifer testing was conducted to measure hydraulic conductivity, transmissivity and storage coefficient. The degree of hydraulic connectivity between the upper and lower aquifers was sufficiently assessed.

- Ground water flow modeling was conducted to evaluate the likely success of a proposed extraction system. The results of this modeling enabled the selection of well configuration and optimal pumping rates that could provide rapid, cost-effective results.

Because the study area described in this case study was well characterized, the ground water extraction and treatment system now in place was well-designed and is working as planned. Although it will be some time before the site can be certified clean, the prognosis for eventual cleanup of the chromium-contaminated ground water appears good.

A.3 Complex Site

Introduction

The complex case history presented here is a regional groundwater problem encompassing approximately one square mile in northern California (Figure A.7). The site includes portions of an industrial research park, a hospital and a residential neighborhood. Volatile organic chemicals (VOCs) in groundwater are migrating from the research park and impacting groundwater beneath the hospital property and residential neighborhood. VOCs are also impacting a Creek which flows through the research park and residential neighborhood.

The area under investigation is comprised of nine sites within the research park, the hospital property, the residential neighborhood and the creek. The nine sites within the research park represent the source areas for contaminants found in the area of investigation. Releases of chemicals from these nine sites have migrated off-site and commingled into a single groundwater plume, which is impacting the regional area of investigation. In addition to the regional investigation, separate investigations and cleanup activities have been undertaken at each of the nine sites.

The Remedial Investigation/Feasibility Study (RI/FS) for the area has been a multi-media investigation. In addition to the groundwater investigation, sampling of air, surface water, and stream sediments and biota have been conducted as components of the regional RI/FS. For the purposes of this case study, however, discussion will be limited to the hydrogeologic investigation.

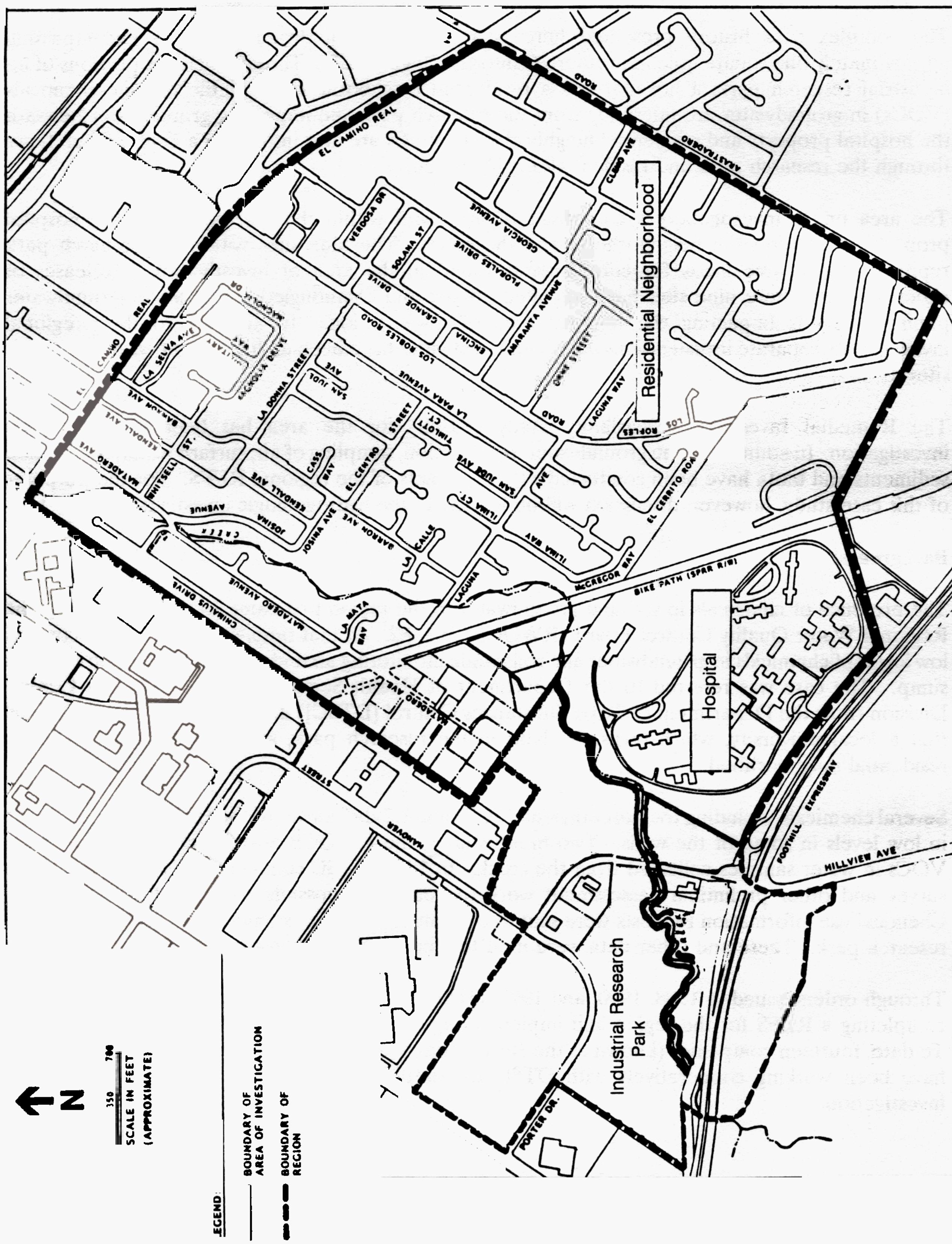
Background

The presence of chemicals in soil and groundwater in the region first came to the attention of the Regional Water Quality Control Board (RWQCB) in 1982. At that time, one company discovered low levels of chemicals in groundwater and soils while monitoring an underground acid neutralization sump. The case was referred to the Department of Health Services, Toxic Substances Control Division (now the Department of Toxic Substances Control [DTSC]) in late 1985. DTSC requested that a local university, which owns the land in the research park, sample private wells in the residential neighborhood.

Several chemicals, including trichloroethylene (TCE) and 1,2-dichloroethylene (1,2-DCE) were found in low levels in some of the wells. Two months later, the RWQCB also found concentrations of VOCs in water samples collected from the creek. In 1987, DTSC conducted an extensive soil gas survey and other preliminary assessment work to determine possible sources of the chemicals. Chemical use information requests were sent to over one hundred past and current operators in the research park. These and other data were used to identify potential responsible parties.

Through orders issued in 1988, 1990, and 1992, DTSC has named 21 companies as responsible for completing a RI/FS for the region and implementing any follow-up actions that may be required. To date, fourteen companies (known as the Responding Parties) are complying with the Order, and have been working cooperatively with DTSC to complete the RI/FS for the regional area of investigation.

Figure A.7. Layout of the complex site area of investigation.



Due to the high level of community interest generated by the discovery of groundwater contamination within the residential neighborhood, a Technical Advisory Committee (TAC) was formed to facilitate communication with the community. The TAC is comprised of representatives from DTSC, the Responding Parties and their consultants, and three members of the community with technical expertise. The TAC provides a forum for data review and discussion of proposed field work.

In addition to the Regional Order, separate Orders were issued to the nine sites within the research park. In an effort to coordinate all of these investigations and ensure consistent and effective data collection, and promote data exchange, DTSC implemented several actions including:

- Standardizing data collection procedures from all borings in the region by requiring that borings be continuously cored, and that boring logs contain the same information regarding soil type, texture, moisture, material size and makeup. This included using the Unified Soil Classification System for recording soil type, Munsell Soil Color Chart for color, and recording the relative percentages of gravel, sand, silt and clay content.

- Requiring that groundwater sampling and water level measurements for all investigations occur at the same time, that samples be analyzed using the same analytical method, and that all wells be surveyed into a common datum.

- Holding geologic "round table" meetings with geologists working on the investigations within the region to promote information exchange and develop a common understanding of the geology and hydrogeology of the region.

- Required the development of a regional database to include information from all sites. In addition, a biannual Data Compilation and Evaluation Report was developed which compiled and evaluated data from all sites, and periodically updated the conceptual hydrogeologic model for the region. Groundwater potentiometric and isoconcentration maps for common contaminants were produced for the entire region.

These actions were necessary due to the complexity of the regional geology and hydrogeology, and the fact that these sites were located in close proximity to each other. Also, these actions ensured that all investigations were consistent, compatible, avoided duplication of efforts, and minimized delays.

Regional Geology

The region is located on the western side of the Santa Clara Valley near San Francisco Bay. The Santa Clara Valley is a large structural depression in the central Coast Range of California. The valley is bounded to the west by the Santa Cruz Mountains and to the east by the Diablo Range. The valley was created by tectonic movement of the San Andreas Fault to the west and the Hayward Fault to the east. The area of investigation encompasses both the lower foothills of the Santa Cruz Mountains and the upper portion of the San Francisco Bay alluvial plain.

The rocks and sediments of the region can be divided into four groups based on time of deposition. The four groups are:

(1) The Franciscan assemblage, consisting of metamorphic rocks which form the basement substrate for the overlying formations.

(2) Volcanic rocks, consisting of black, columnar jointed basalt flows interbedded with minor sandstone and claystone, and marine sedimentary rocks, which include sandstone, dolomitic limestone and light green shale.

(3) The Santa Clara Formation, which originates from erosion of Franciscan assemblage rocks and deposition in alluvial fans. This formation consists of moderately well-consolidated subaerial deposits of reddish-brown gravel, sand, silt and clay in lenticular beds.

(4) Quaternary Terrestrial Sediments: alluvial sediments consisting of unconsolidated to moderately consolidated flat-lying sand, gravel, silt, and clay deposits, with a predominance of sandy gravel and gravelly sand, derived from creeks in the Santa Cruz Mountains.

Three major unconformities are evident in the region. The oldest unconformity exists between the Franciscan assemblage and the volcanic and marine sedimentary rocks, and represents a 50 to 100 million-year gap in time. The next youngest unconformity represents a change from a marine to a terrestrial depositional environment and is indicative of an orogenic event. The youngest unconformity exists between the Santa Clara Formation and Holocene alluvium deposits, in which flat-lying, undeformed alluvial sediments rest on folded or dipping sedimentary rocks (Santa Clara Formation).

Pre-Quaternary strata in the region have been deformed by folding. The folding is evident as dipping beds. Thrust faulting at depth, associated with the geologically young, tectonically active Santa Cruz Mountains, is believed responsible for the folding. The marine sedimentary rocks exhibit dips between 40 and 60 degrees to the northeast. The Santa Clara Formation also dips northeast up to 30 degrees.

Several faults have been inferred in the region. The location of one inferred fault within the hospital property appears to have been verified during the regional investigation. Boreholes drilled to 200 to 300 feet on either side of this feature indicate approximately 70 feet of offset based on gamma ray log and resistivity log correlations. The evaluation of the effect of this fault on groundwater flow has not been completed as of this writing.

Site Geology

The major geologic units identified in the area of investigation are designated as alluvium, the Santa Clara Formation Younger Sequence, and the Santa Clara Formation Older Sequence. All are composed of interbedded gravels, sands, silts, and clays. The volcanic rocks and marine sediments occur only in the research park. Figure A.8 is a block diagram showing the spatial relationships among these units.

Alluvium covers most of the area of investigation. This nearly flat-lying unit is up to 35 feet thick at the hospital property and up to 105 feet thick in the residential neighborhood.

The Younger Sequence underlies the Alluvium in the residential neighborhood and the eastern portion of the hospital property. This unit is up to 270 feet thick. From approximately the eastern property boundary of the hospital property to Laguna Avenue in the residential neighborhood, the Younger Sequence beds dip northeast from 2 to 30 degrees.

The Older Sequence underlies the Younger Sequence in the residential neighborhood and directly underlies Alluvium across most of the hospital property, where the Younger Sequence has been removed by erosion. This unit is in excess of 400 feet thick. The Older Sequence exhibits bedding slopes ranging from a few degrees in a southwesterly direction to approximately 30 degrees in a northeasterly direction. The Older Sequence sediments are more heterogeneous and contain fewer continuous permeable sand beds than the Younger Sequence.

Hydrogeology

In the area of investigation, groundwater is encountered in continuous and discontinuous water-bearing strata of the alluvium and the Santa Clara Formation. First groundwater is generally at depths ranging from approximately 12 to 30 feet below ground surface (bgs).

Alluvium comprises one aquifer (Zone A) at the hospital property and two aquifers (Zones A and B) at the residential neighborhood. Alluvial groundwater is primarily unconfined at the hospital property and western portions of the residential neighborhood, and confined in the central and eastern portions of the residential neighborhood. At the hospital property, Zone A groundwater is first encountered at depths ranging from approximately 12 feet to 18 feet bgs. The saturated thickness is approximately 1 to 12 feet. In the residential neighborhood, Zone A groundwater is first encountered at depths ranging from approximately 20 to 40 feet bgs. The saturated thickness of Zone A varies with water-table fluctuations and ranges from approximately 8 to 15 feet. Zone B underlies the aquitard that forms the bottom of Zone A. Zone B is confined and varies in thickness from 10 to 15 feet.

Flow within Zone A is directed to the east near the western boundary of the hospital property, and to the northeast in the northern and eastern portion of the hospital property. Flow within the residential neighborhood Zone A is directed to the east and northeast on the east side of the creek, and to the north and northwest on the west side of creek. Flow in Zone B is directed to the north and northeast.

Groundwater occurs in the Younger Sequence in the residential neighborhood and the easternmost portion of the hospital property. The three predominant Younger Sequence aquifers are designated as Zone C, Zone D, and Zone E. These sand and gravel sediments are continuous across relatively large portions of the residential neighborhood. The groundwater flow within the three Younger Sequence aquifers is directed to the northeast and east. A clay interval ranging up to 60 feet thick separates Zone C from the overlying Zone B. In most boreholes, Zone D consists of three or four sand or gravelly sand intervals up to 12 feet thick, which are interbedded with silty clay. Beneath Zone D is a clay interval, approximately 50 to 100 feet thick. Flow Zone E is defined as a group of sand beds up to 15 feet thick. Beneath Zone E is an aquiclude of clay and clayey sands ranging up to 17 feet thick.

Surface Water

The creek is the major surface water feature in the area of investigation, flowing east out of the Santa Cruz Mountains and then east and north through the research park, hospital property, and residential neighborhood. It is a perennial stream throughout most of the area of investigation. Creek flow rates show a strong seasonal variation, with the highest flows occurring from November through May, and the lowest occurring from June through October. The creek gains and loses water to the alluvium and the Santa Clara Formation in the area of investigation. The alluvium discharges ground water to the creek near the hospital property. Beyond this location, the creek is incised in the Santa Clara Formation Older Sequence and likely loses water where it encounters permeable materials. Some groundwater also seeps into the creek through the Older Sequence between the

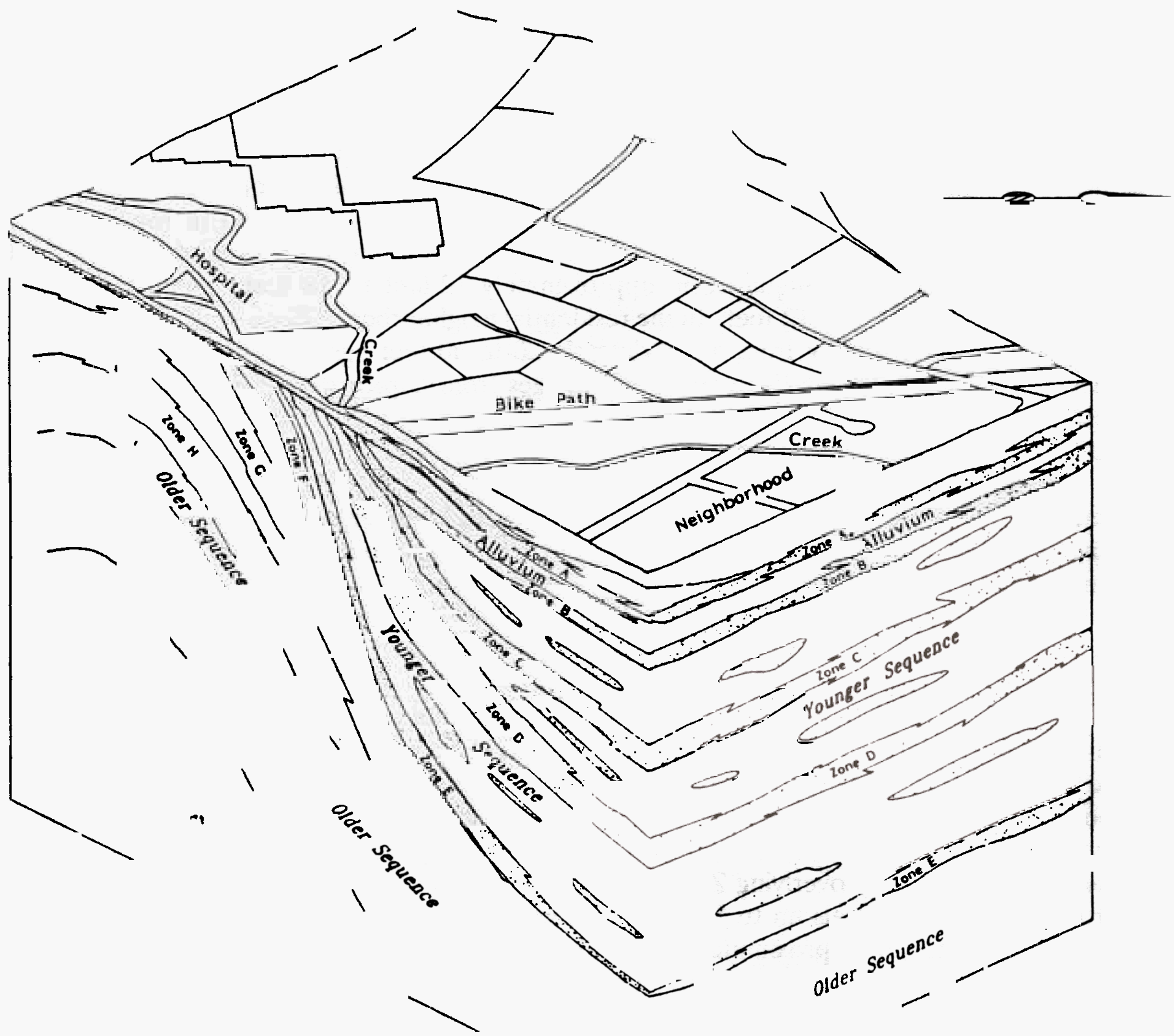


Figure A.8. Block diagram of the regional geology of the complex site.

hospital property and a nearby bike path. Downstream of the bike path, the creek discharges to the Zone A alluvium in the residential neighborhood.

Scoping Activities

Initial data regarding the region were available from several sources including published reports (U.S. Geological Survey and other reports), site-specific investigation reports (from the sites within the research park), and reports on previous private well and creek sampling episodes. A working hypothesis and conceptual model were developed based on an evaluation of these data which included the following elements:

- Groundwater flow and contaminant transport in the alluvial deposits in the region were likely to be within discontinuous water bearing materials.

- Saturated alluvium was not extensive within the research park, and was generally limited to areas near the creek. The unconformity between the alluvium and the underlying Santa Clara Formation was thought to be relatively impermeable and would inhibit the downward migration of chemicals. The alluvium was considered more permeable than the underlying Santa Clara Formation.

- The creek received ground water discharge within the research park, and lost water as the creek flowed through the residential neighborhood. Groundwater elevations within the residential neighborhood were 10-20 feet below the creek bed, suggesting that the creek was a source of recharge to the underlying groundwater and a transport pathway for chemical migration.

- Two topographic highs, composed of Santa Clara Formation sediments, were located in an area between the research park and the residential neighborhood. These highs were suspected to behave as poorly transmissive abutments, constricting alluvial ground water flow in this area.

- Groundwater gradients abruptly steepened between the hospital property and the residential neighborhood, suggesting either a stratigraphic contact or fault.

Data needs for the investigation included determining the sources for VOCs in groundwater, the vertical and lateral extent of ground water contamination, and the migration pathways for chemical constituents. The workplan would address these data needs by investigating the distribution of contaminants, the vertical and horizontal stratigraphy, and the interaction between creek flows and ground water within the area of investigation.

Remedial Investigation Summary

Phase I Investigation

The RI/FS workplan and Groundwater Field Sampling Plan, initially developed for the regional investigation, were designed for a traditional phased investigation. That is, a report summarizing the first phase of field work and a workplan identifying additional field work would be submitted to DTSC. This process would continue until the investigation was complete. The objectives of the first phase were to provide data regarding the general distribution of VOCs in the shallow water-bearing zone throughout the area of investigation, determine whether VOCs were present within deeper water-bearing zones of the Santa Clara Formation, and evaluate the interaction between surface water and shallow groundwater along different reaches of the creek. Additionally, the first phase would evaluate whether the unconformity between the Alluvium and Santa Clara Formation would inhibit groundwater flow and chemical migration. Subsequent phases would complete the definition of chemical distribution, evaluate the fate and transport of chemicals and any needed additional work.

To ensure consistency and facilitate rapid completion of the field work, the Groundwater Field Sampling Plan contained specific methods and procedures regarding drilling methods, borehole logging, well construction, development and sampling. All future phases of field work would utilize methods and procedures contained in the Groundwater Field Sampling Plan.

The first phase included the installation of monitoring wells at 19 locations, including cluster wells at three locations along the creek. The cluster wells were installed first to maximize data collection and ensure that appropriate field modifications for downgradient well locations could be made, if necessary. Pilot holes were continuously cored at cluster well locations to 125 feet using mud rotary drilling methods. Geophysical logging (including self potential, resistivity, natural gamma, and caliper logs) was conducted for each pilot hole. The remaining shallow monitoring wells were completed using hollow stem augers. To ensure the collection of representative data, wells were constructed with maximum screen lengths of 10 feet; well screen and filter packs were designed based on sieve analysis of representative samples of the water-bearing materials. Wells were surveyed to a common regional datum, and water level measurements and water samples were taken following well development.

The results of the first phase indicated that the regional investigation would be far more complex, costly and time-consuming than was originally anticipated. Contamination was detected in deeper water-bearing zones, contamination of the shallow groundwater beneath the residential neighborhood was extensive, and the interaction between the creek and shallow groundwater, particularly along the reach of the research park, was complex. It was clear that an alternative to a traditional phased investigation was necessary to complete the investigation in a timely and cost effective manner.

Phase II Investigation

The alternative investigative approach developed (known as Phase II) was a multi-task approach utilizing rapid field evaluation techniques within a flexible investigative framework. The investigation utilized preplanned procedures and decision criteria, and data transmittals at key decision points in place of traditional summary reports and workplan submittals to facilitate communication and decision making. Meetings and conference calls with the TAC were held as needed to discuss investigative findings and proposed new field work.

Field work necessary to address data gaps were identified quickly, and was submitted via letter workplans referencing preapproved procedures. These workplans would summarize the existing data, evaluate the identified data gaps, define the objectives for the field work proposed, and detail the technical approach to be utilized. The workplans contained decision criteria and contingency plans to address field situations and allow the work to continue. This methodology maximized data collection and allowed for the relatively rapid assessment of the vertical and horizontal distribution of contaminants, and the identification of remaining data gaps. Proposals to address these data gaps were developed quickly, while field work to define the plume boundaries was completed.

This flexible approach allowed multiple field tasks to be conducted in parallel, and enabled the investigation to continually evaluate data and identify data gaps. Efforts were directed towards gathering the data necessary to characterize the site instead of report writing and review. The successful use of this methodology was contingent on the thorough scoping of data and the clear delineation of the field objectives and technical approach.

The initial steps of the Phase II investigation concentrated on defining the plume in three dimensions, while the final steps focused on gathering the data necessary to complete the FS. Therefore, field tasks were directed towards completing the definition of groundwater contamination, geology and hydrogeology, the study of creek-groundwater interaction, and the evaluation of hydraulic properties of water bearing zones.

The approach utilized in-situ ground water sampling (a rapid field evaluation method) as the keystone to the field program. This method could collect multiple discrete in-situ groundwater samples during the course of advancing a borehole. The sampler is lowered down the hollow drill string and driven ahead into the target water-bearing zone. A syringe-type sampler was then used to collect an undisturbed groundwater sample into stacked evacuated glass sampling tubes connected by double ended syringes (see Figure A.9). Additional sampling tubes could be lowered down the drill string to collect duplicate samples. The sampler was decontaminated on-site between uses.

Samples obtained from the in-situ ground water sampler were analyzed using EPA Method 8010 at a state certified mobile laboratory. These ground water samples, collected during Phase II, were found to correlate very well with samples obtained from monitoring wells. The use of the on-site mobile lab allowed decisions to be made quickly as to whether a target zone was clean or whether additional sampling (deeper or downgradient) was necessary.

Phase II utilized in-situ ground water sampling in a multi-task approach, consisting of several steps. Step 1 focused initially on strategic locations within and between the hospital property and the residential neighborhood. These strategic data were subsequently used to modify or "fine tune" predetermined downgradient sampling locations during Steps 2 and 3 (see Figure A.10).

The framework of the investigation was designed to collect hydrogeologic and contaminant distribution data in three dimensions. The in-situ ground water sampling system, combined with continuous coring and geophysical logging of boreholes, collected initial data regarding hydrogeology and chemical distribution. Monitoring wells were installed to verify in-situ sampling results and assess water levels and flow directions at specific locations.

Exploratory boreholes were drilled using mud rotary methods and were continuously cored to a specific depth (generally 200 feet), and geophysically logged. The exploratory boreholes were temporarily sealed using bentonite clay to prevent cross contamination of water-bearing zones and maintain the borehole in case it had to be advanced deeper. After target water-bearing zones were identified, a second boring (usually located within 10 feet of the exploratory borehole) was advanced to the target depth and a in-situ ground water sample was obtained. Mud rotary methods were used to minimize cross-contamination of water-bearing zones. The boring was advanced until all of the target water-bearing zones were sampled, or until samples from two consecutive zones did not detect any chemicals. If contaminants were detected in the deepest sample, the exploratory boring was advanced in 100-foot increments and additional water-bearing zones would be identified and sampled. Wells were generally installed at the shallowest water-bearing zone where chemicals were not detected, or that zone and the most contaminated zone identified in the borehole, depending on the in-situ ground water sampling results. The use of bentonite clay allowed the exploratory borehole to be reamed out and utilized for monitoring well construction, if needed. Following an evaluation of the data, additional wells were later installed in specific water-bearing zones of interest.

Data collected during the early steps of the Phase II investigation indicated that beds within the Santa Clara Formation were dipping northeasterly at approximately 5 to 10 degrees beneath the hospital property and approximately 28 degrees between the hospital property and the residential neighborhood. Beds beneath the residential neighborhood were determined to be generally flat-lying. No evidence of faulting was found between the hospital property and the residential neighborhood as was hypothesized during scoping at the beginning of the investigation. Dipping beds found between the hospital property and the residential neighborhood were determined to be the cause of the steep groundwater gradients in this area. These dipping beds were also determined to have a significant effect on contaminant transport, and required additional investigation.

Subsequent field work was conducted (Steps 4 through 6) to address specific data gaps involving contaminant distribution and transport, particularly regarding the deeper water-bearing zones within the dipping Santa Clara Formation. One bed within the Santa Clara Formation was found to have a distinctive geophysical signature and lithology, and was utilized as a marker bed during the investigation. This marker bed was invaluable for identifying and tracing deeper contaminated zones. The use of continuous coring methods and the in-situ ground water sampling system allowed the rapid collection of data in specific areas. Monitoring wells were also installed in specific water-bearing zones identified with in-situ ground water sampling. Additional aquifer tests and slug tests were conducted in several locations to evaluate the hydraulic properties of specific aquifers and to evaluate the interconnection between the various water-bearing zones.

During Phase II, a detailed investigation of the interaction between the Creek and shallow groundwater was performed. A series of piezometers were installed along the creek upstream of the residential neighborhood. The results of this investigation indicated that the creek was receiving contaminated groundwater from the shallow alluvium along portions of the creek, and was losing water to exposed beds of the dipping Santa Clara Formation along other portions of the creek.

The results of the investigation indicate that contamination beneath the residential neighborhood is relatively low (0.5 to 17 μg/l TCE) and shallow (30 to 70 feet), although laterally extensive within Zones A and B. Significantly higher levels of TCE (300 to 1000 μg/l) were found in the shallow alluvium beneath the hospital property. Deeper water-bearing zones within the Santa Clara Formation, beneath the hospital property and between the hospital property and the residential neighborhood, contained TCE at concentrations up to 200 μg/l (in Zones C through E). VOCs were identified in the Santa Clara Formation Younger Sequence to a maximum depth of 320 feet. A list of VOCs found in groundwater in the area of investigation are listed in Table A.1.

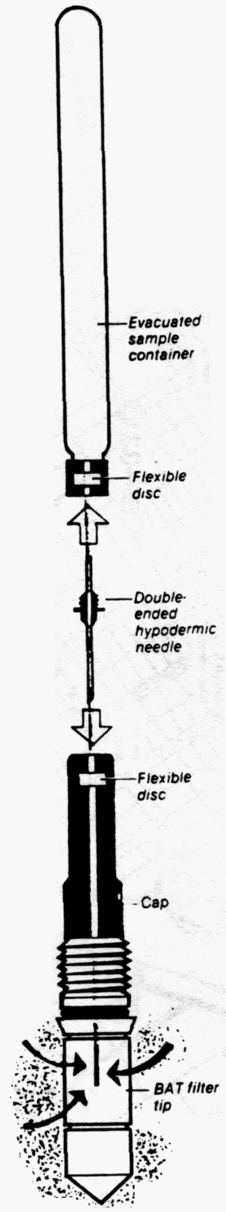
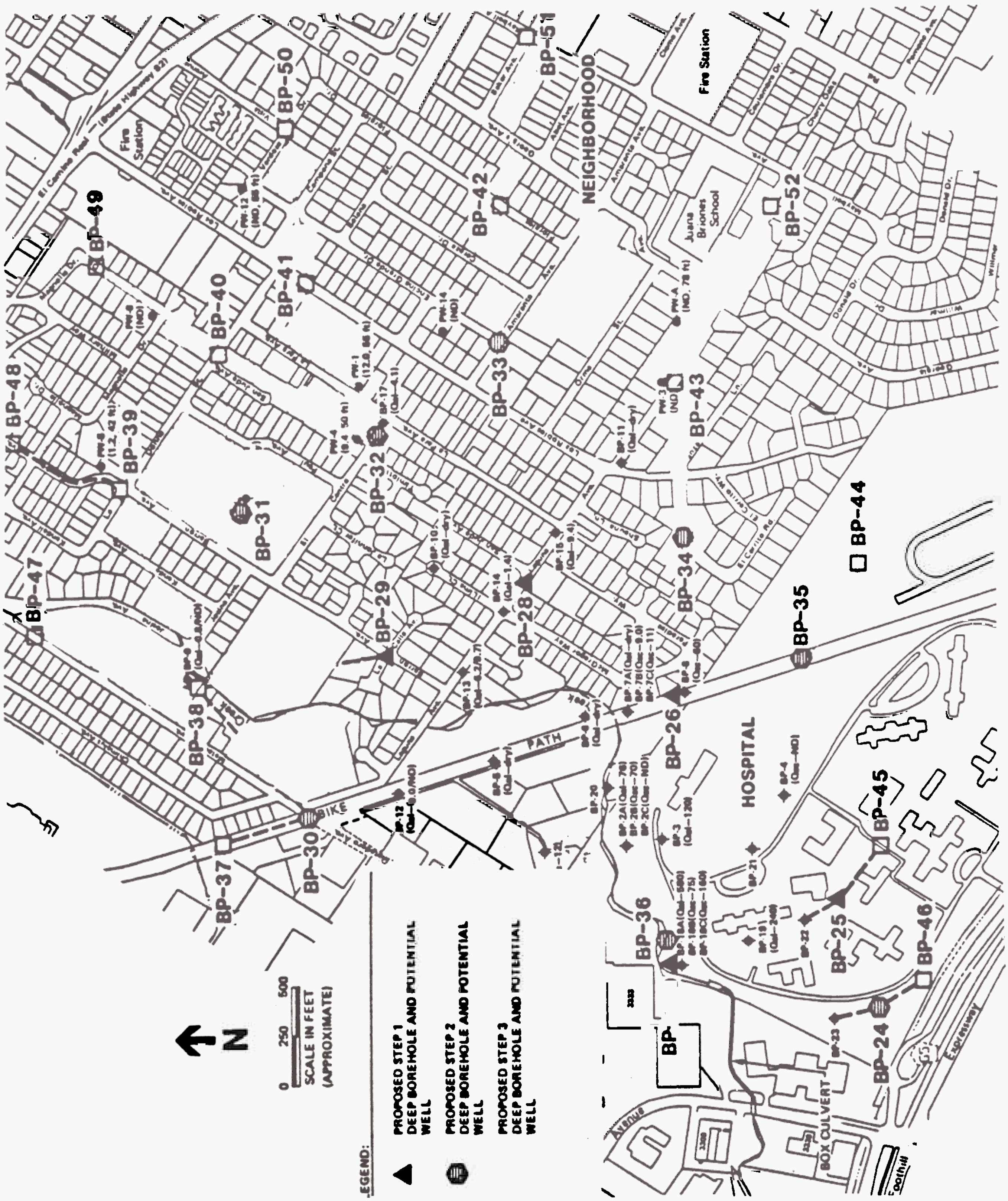


Figure A.9. Diagram of the in-situ ground water sampling system used during the field investigations. Courtesy of Hogentogler and Company Inc. (Use of trade names does not constitute endorsement).

Figure A.10. Borehole and well locations for the Phase II investigation



The Alluvium is considered to be fairly transmissive with transmissivities calculated from pump tests ranging from 0.08 ft^2/min to 3.62 ft^2/min. The Santa Clara Formation is generally considered poorly transmissive, with transmissivities calculated from pump tests ranging from 0.0032 ft^2/min to 0.42 ft^2/min.

Interim Remedial Actions

The direct result of this early data evaluation was the initiation of interim remedial actions. Although the RI/FS for the region has not been completed, several interim remedial actions have been implemented or are currently under development (see Figure A.11). Soil and groundwater interim remedial actions have been implemented at several of the nine sites within the research park. Remedial Action Plans have been completed for five of the nine sites to date. Cleanup of the nine sites (i.e., source control) is a critical component of the overall regional cleanup.

An interim aeration system was installed in the creek, to remove VOCs from the creek water before it flowed into the residential neighborhood. The aeration system uses a series of air diffusers which are installed directly into the creek to force air bubbles through the water to volatilize the VOCs. This system has a dual purpose: 1) to minimize exposure to creek water containing VOCs and 2) to prevent the recharge of groundwater with contaminated creek water. This system began operation in March 1993.

Additionally, interim groundwater extraction systems are currently under development to remediate the highly contaminated shallow Alluvium beneath the hospital property and portions of the research park, and to intercept shallow and deep contaminated groundwater between the hospital property and the residential neighborhood. These systems will consist of two horizontal extraction wells in the shallow Alluvium on the hospital property and a series of vertical extraction wells in several water-bearing zones between the hospital property and the residential neighborhood. Extracted groundwater from the systems will be piped to a centralized treatment system located within the research park. The treated effluent will be discharged to the creek. These systems are expected to be operational by Summer 1994. These systems will also be key components of the final remedial action for the region.

Summary

The successful completion of the regional investigation in a timely and cost effective manner was the direct result of using a multi-task investigative approach. The multi-task approach utilized rapid field evaluation techniques within a flexible investigative framework to complete multiple field activities. The investigation utilized preplanned procedures, decision criteria and data transmittals at key decision points, in place of traditional summary reports and workplan submittals, to facilitate decision making and communication. The use of the in-situ ground water sampling system in conjunction with continuous coring of boreholes enabled the rapid collection of hydrogeologic and chemical data over a large area (approximately one square mile) within a complex geologic setting. In-situ ground water samples were collected at 41 locations from depths up to 500 feet. A total of 101 monitoring wells and 32 piezometers were installed in the regional area of investigation. Continuous discharge aquifer tests and slug tests were also conducted during the investigation. Aside from an initial 25 monitoring wells, the investigation was completed in approximately 25 months.

Table A.1. Summary of ground water analytical data from the Remedial Investigation.

Parameters	Frequency of detection[b]	Number of positive results	Concentration (micrograms per liter) Range	Arithmetic Average[c]
Trichloroethene (TCE)	0.696	454	<0.5-3000	
Chloroform	0.437	285	<0.5-63	2.54
1,1-Dichloroethene (1,1-DCE)	0.352	230	<0.5-170	6.02
1,2-Dichloroethene (1,2-DCE)	0.265	173	<0.5-1800	4.60
Tetrachloroethene (PCE)	0.259	169	<0.5-100	2.76
1,1,1-Trichloroethane (1,1,1-TCA)	0.221	144	<0.5-360	3.42
1,1-Dichloroethane (1,1-DCA)	0.152	99	<0.5-16	0.74
Trichlorotrifluoroethane	0.127	83	<0.5-90	0.92
Dichlorodifluoromethane	0.090	59	<0.5-180	1.92
Trichlorofluoromethane	0.069	45	<0.5-7.1	0.57
Bromodichloromethane	0.050	29	<0.5-13	0.57
Toluene[d]	0.040	9	<0.5-1.7	0.44
Dibromochloromethane	0.024	14	<0.5-5.7	0.48
Xylene (Total)[d]	0.005	3	<0.5-3.0	0.38
	0.004	1	<0.5-0.8	0.38
Ethylbenzene[d]	0.004	1	<0.5-0.5	0.38
,2 Dichloroethane	0.003	2	<0.5-2.3	0.47
Vinyl chloride	0.002	1	<0.5-3.0	0.47

[a]Data set from August 1990 through April 1993; does not include data from private wells. Summary does not include data from in-situ borehole (BAT) samples.
[b]Frequency of detection calculated by dividing the number of positive detections by the total number of samples.
[c]Average calculated using one-half of the analytical detection limit for samples that did not identify the VOC.
[d]Chemical was not analyzed after August 1991.

This flexible investigative approach has applicability at other hazardous substances release sites. Through adequate project scoping and advance planning, the use of rapid field evaluation methods can expedite hydrogeologic investigations. Scoping activities should be continued throughout the project to ensure that all data necessary to complete the RI/FS are collected. Workplans which adequately scope existing data, evaluate the identified data gaps, and clearly define objectives and technical approaches for the proposed field work can expedite the completion of an investigation. The use of letter workplans, referencing preapproved procedures, can minimize delays and allow efforts to be directed towards completion of field activities.

It is also important to continually evaluate opportunities for the early implementation of interim remedial actions. Proposed interim remedial actions should be consistent with anticipated final remedial actions for the site, and should, if possible, represent early implementation of portions of the final cleanup.

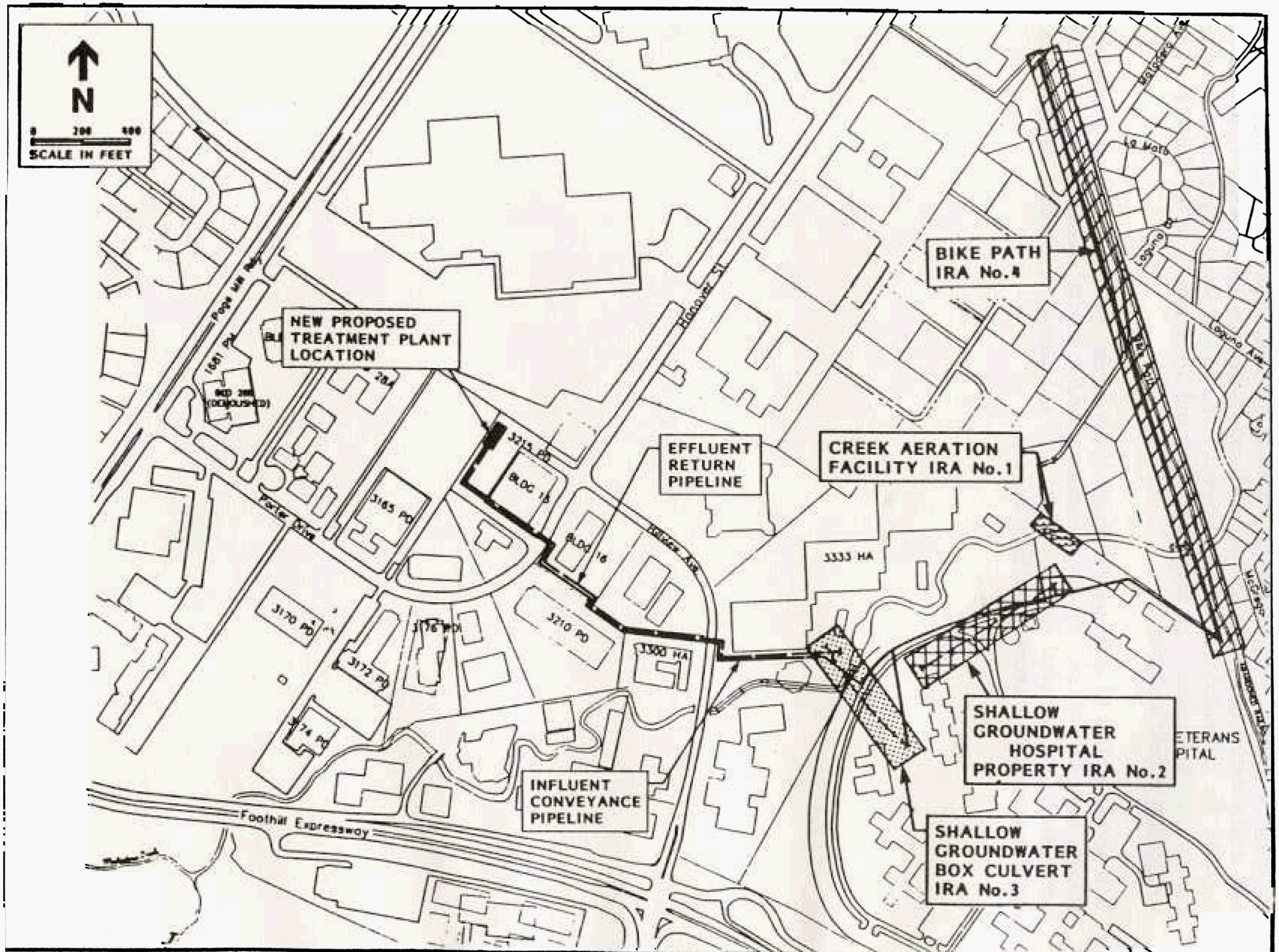


Figure A.11. Locations of Interim Remedial Actions.

APPENDIX B. SOURCES OF INFORMATION FOR PROJECT SCOPING (modified from USEPA, 1991)

GENERAL DATA SOURCES

Source	Information Obtainable	Comments
Libraries	Earth science bibliographic indices	Many of the types of information discussed below can be obtained from libraries. Excellent library facilities are available at the U.S. Geological Survey offices (USGS) in Reston, VA; Denver, CO; and Menlo Park, CA. Local university libraries can contain good collections of earth science and related information and typically are repositories for Federal documents. In addition, local public libraries normally have information on the physical and historical characteristics of the surrounding area.
Computer literature searches	Bibliographic indices	Perhaps one of the most useful and cost effective developments in the bibliographic indexes has been the increased availability of computerized reference searches. On-line computer searches save significant time and money by giving rapid retrieval of citations of all listed articles on a given subject and eliminate manual searching of annual cumulated indexes. A search is done by use of keywords, author names, or title words, and can be delimited by ranges of dates or a given number of the most recent or oldest references. The average search requires about 15 minutes of online searching and costs about $50 for computer time and offline printing of citations and abstracts.
Dialog	Accesses over 350 data bases from a broad scope of disciplines including such data bases as GEOREF and GEOARCHIVE.	Provides indexes to book reviews and biographies; directories of companies, people, and associations; and access to the complete text of articles from many newspapers, journals, and other original sources. Subscriptions and information: 1-800-3-DIALOG.
USGS ISD Bulletin Board System USGS Reston, VA 22092 Data:(703) 648-4168 Voice:(703) 648-7127	This board has three conferences: sysops, dBase, and CD-ROM.	Although geared toward USGS and government employees, the board is open to the public in the CD-ROM conference. In addition to the conferences, the board has the typical uses of messaging and file transfers, with the sysop tracking software that would benefit the USGS or its employees.

Source	Information Obtainable	Comments
Master Directory (MD) User Support National Space Science Data Center (NSSDC) Goddard Space Flight Center Greenbelt, MD 20771 (301) 794-5186 Span: NCF::SHIPE	The MD is a multidisciplinary data base that covers earth science (geology, oceanography, atmospheric science), space physics, solar physics, planetary science, and astronomy/ astrophysics. It describes data generated by NASA, NOAA, USGS, DOE, EPA, and other agencies and universities.	MD is a free on-line data information service. Data available include personnel contact information, access procedures to other data bases, scientific campaigns or projects, and other data sources. Access Procedures: MD resides on a VAX at NSSDC and may be reached by several networks. MD is option #1 on the menu of NSSDC's On-line Data Information Services (NODIS) account. From span nodes: $SET HOST NSSDA. USERNAME:NSSDC (no password). From Internet: $TELNET NSSDC.GSFC.NASA.GOV or $TELNET 128.183.10.4. USERNAME:NSSDC (no password). Via Direct Dial: Set modem to 8 bits, no parity, 1 stop bit, 300,1200 (preferable), or 2400 band. Dial (301) 286-9000 ENTER NUMBER: MD, CALL COMPLETE: [CR], USERNAME: NSSDC (no password). For assistance or more information, contact the MD User Support Office (301) 794-5186.
Alternative Treatment Technology Information Center (ATTIC) ATTIC Proj. Officer U.S. EPA 3202 Tower Oaks Blvd. Suite 200 Rockville, MD 20852 (301) 816-9153 Online (301)230-2216	ATTIC is an EPA data base that contains information from the following resources: SITE Program, Industry Studies and Data, Records of Decision (ROD), NATO/ International Studies, COLIS Technical Information Exchange (TIX), RCRA Delisting Actions, State Agencies, Cost of Remedial Action (CORA) Model, RREL Water Treatability Database, RSKERL Soil Transport and Fate Database, Hazardous Waste Collection Database, Historical User File, Treatability Studies, Geophysics Advisor Expert System, USATHAMA IR Reports, Technical Assistance Directory, OSWER Bulletin Board, Commercial Databases, Regional Databases.	Requires registration with the U.S. Environmental Protection Agency in order to gain access to the data base.

Source	Information Obtainable	Comments
Earth Science Data Directory (ESDD) U.S. Geological Survey (USGS) 801 National Center Reston, VA 22092 (703) 648-7112 FTS 959-7112	ESDD is a data base that contains information related to the geologic, hydrologic, cartographic, and biological sciences.	Also included are data bases that reference geographic, sociologic, economic, and demographic information. Information comes from worldwide data sources and data includes that from NOAA, NSF, NASA, and EPA.
University sources	Engineering and geology theses	College and university geology theses, in most instances, are well-documented studies dealing with specific areas, generally prepared under the guidance of faculty members having expertise in the subject under investigation. Most theses are not published.
Comprehensive dissertation index	Doctoral dissertations	Citations began in 1861 and include almost every doctoral dissertation accepted in North America thereafter. The index is available at larger library reference desks and is organized into 32 subject volumes and 5 author volumes. Specific titles are located through title keywords or author names. Ph.D. dissertations from all U.S. universities are included.
AGI Directory of Geoscience Department	Faculty Members	Regular updates of faculty, specialties, and telephone date.
DATRIX II University Microfilms International 300 North Zeeb Rd. Ann Arbor, MI 48106 (800) 521-3042 ext. 732 (313) 761-4700 (in Alaska, Hawaii, and Michigan)	Dissertations and Masters theses	Using title keywords, a bibliography of relevant theses can be compiled and mailed to the user within one week. In addition, the DATRIX Alert system can automatically provide new bibliographic citations as they become available.
National Cartographic Information Center U.S. Geological Survey 507 National Center Reston, VA 22092 (703) 860-6045	Land use and land cover maps are available. Four other sets of associated maps are also available: political units, hydrologic units, census county subdivisions, and Federal land ownership.	Master sets of land use and land cover and associated maps for a particular area are on open file and are available for reproduction at any USGS National Cartographic Information Center (NCIC).

Source	Information Obtainable	Comments
United States Geology: A Dissertation Bibliography by State	Ph.D. dissertation or Masters theses	Free index from University Microfilms International. Some universities do not submit dissertations to University Microfilms for reproduction or abstracting, however, and the dissertations from these schools do not appear in the United States Geology index. Citations for dissertations not abstracted should be located through DATRIX II or Comprehensive Dissertation Index.
Dissertation Abstracts International, Volume B - Science and Engineering, a monthly publication of University Microfilm International	Extended abstracts of dissertations from more than 400 U.S. and Canadian universities	Once the citation for a specific dissertation has been obtained from the Comprehensive Dissertation Index or from DATRIX II, the abstract can be scanned to determine whether it is relevant to the project at hand. Since some universities do not participate, some theses indexed in the two sources listed above should be obtained directly from the author or the university at which the research was completed.
Dissertation Abstracts International (continued)		Abstracts of Masters theses available from University Microfilms are summarized in 150-word abstracts in Masters Abstracts and are indexed by author and title keywords. Both Dissertation Abstracts International and Masters Abstracts are available at many university libraries. A hard (paper) or microform (microfilm or microfiche) copy of any dissertation or thesis abstracted can be purchased from University Microfilms.
USGS Publication Manuscripts System (PUBMANUS) Earth Science Information Center 507 National Center Reston, VA 22092 (703) 648-6045	This data base provides referral to all U.S. Geological Survey publications.	Flexible searching techniques enable users to find information in numerous ways. Currently, search requests are accepted through the USGS Public Inquiries Division at no charge. (800) USA-MAPS. The "Guide to Obtaining USGS Information" is also an excellent source. It describes the services provided by USGS information offices. Includes addresses and telephone numbers, and lists types of publications and information products and their sources. Publication is free and may be ordered from USGS Book and Report Sales. This guide can be obtained from USGS, Book and Report Sales, Box 25425, Denver, CO 80225, (303) 236-7476.

Source	Information Obtainable	Comments
U.S. Geological Survey (USGS) Earth Science Information Center (ESIC) Reston, VA (703) 860-6045	Detailed topographic, geologic, and hydrologic information is available from the USGS through the Earth Science Information Center. United States historical, physical divisions, Federal-aid highways, national atlas and scientific maps.	ESIC can be contacted to determine which map best meets your needs. Maps can be purchased from: USGS Map Sales Box 25286 Denver, CO 80225 (303) 236-7477
Electric Power Research Institute (EPRI) ATTN: EPRI Technical Information Specialists 3412 Hillview Ave. Palo Alto, CA 94304 (415) 855-2411	Up-to-date compilation of research relevant to utilities.	The EPRI manages a research and development program on behalf of the U.S. electric power industry. Its mission is to apply advanced science and technology to the benefits of its members and their customers.
RCRA/Superfund Hotline Office of Solid Waste (OS-305) U.S. EPA 401 M Street, SW Washington, DC 20460 (800) 424-9346 (toll free) (Washington, DC metropolitan area) (703) 920-9810	Information on RCRA, CERCLA, SARA, and UST statutes and corresponding regulations. Also provides document distribution service, including relevant Federal Register notices.	Team of information specialists maintains up-to-date information on the various regulations and rulemakings in progress. Hours of operation 8:30 a.m. to 7:30 p.m. (EST) Monday through Friday. Answer questions from wide range of callers - consultants, attorneys, generators, transporters, facility owner/operators, State and Federal regulatory agencies, trade associations, and the general public.
California Environmental Protection Agency Office of Environmental Information P.O. Box 2815 Sacramento, CA 95819 (916) 327-1848	Hazardous Waste and Substances Site List	This list (also known as the Cortese List) contains sites identified through several state programs. It can be obtained in two forms: a statewide listing and by zip code. A nominal fee is charged.

Source	Information Obtainable	Comments
California Department of Toxic Substances Control 400 P Street P.O. Box 806 Sacramento, CA 95812-0806	Numerous data bases relating to DTSC activities, including: •CalSites - a listing of known and potential sites and their status •HAZNET - a listing of hazardous waste generators and facilities •IES - a tracking system for complaints and enforcement actions against facilities •RCRIS - a tracking system for all RCRA-funded DTSC regulatory activities	These data bases are for internal department use and can only be accessed through the DTSC. Limited search capabilities are available. Searches are usually available free-of-charge to government agencies, a nominal fee may be assessed for private individuals or organizations.
California Department of Toxic Substances Control Technology Clearinghouse 400 P Street P.O. Box 806 Sacramento, CA 95812-0806 (916) 322-3670	Technology Evaluation Reports	Assessments of remedial technologies
California Department of Toxic Substances Control Office of External Affairs 400 P Street P.O. Box 806 Sacramento, CA 95812-0806 (916) 322-0476	Newsletters Press releases Fact sheets	Information relating to regulatory requirements and summaries of DTSC activities at specific sites
Other Local, State, Federal, and Regional Agencies	Site specific assessment data	Pertinent reports may be obtained or reviewed by contacting the responsible agency.

TOPOGRAPHIC DATA

Source	Information Obtainable	Comments
Branch of Distribution U.S. Geological Survey Maps Sales Box 25286, Federal Center Denver, CO 80225 (303) 236-7477	Index and quadrangle maps for the eastern U.S. and for states west of the Mississippi River, including Alaska, Hawaii, and Louisiana. Other scales are available.	A map should be ordered by name, series, and state. Mapping of an area is commonly available at two different scales. The quadrangle name is, in some instances, the same for both maps; where this occurs, it is especially important that the requestor specify the series designation, such as 7.5 minute (1:24,000), 15 minute (1:62,500), or two-degree (1:250,000).
Commercial map supply houses	Topographic and geologic maps.	Commercial map supply houses often have full state topographic inventories that may be out of print through national distribution centers.
Topographic Database National Geophysical Data at NOAA Code E/GCI 325 Broadway Boulder, CO 80303 (303) 497-6900	A variety of topography and terrain data sets available for use in geoscience applications.	The data were attained from U.S. government agencies, academic institutions, and private industries.
U.S. Geological Survey Topographic Map Names Database Manager, GNIS USGS 523 National Ctr. Reston, VA 22092 (703) 648-4544	This database contains descriptive information and official names for approximately 55,000 topographical maps prepared by the USGS, including out-of-print maps. Data includes current and historical names for each map, geographic coordinates, amp scale, name of state, and other descriptive information.	Printouts and searches are available on a cost recovery basis.
Geographic Information Retrieval and Analysis System USGS Earth Science Information Center 507 National Center Room 1-C-402 Reston, VA 22092 (800) USA-Maps (703) 648-6045	Land use maps, land cover maps, and associated overlays for the United States.	These maps have been digitized, edited and incorporated into a digital data base. The data is available to the public in both graphic and digital form. Statistics derived from the data are available also. Users are able to search for either locations or attributes. To obtain information from this data base, contact ESIC.

Source	Information Obtainable	Comments
U.S. GEODATA Tapes Washington, DC of the Interior Bldg. 18th & C Sts., NW Washington, DC 20240 (202) 208-8073	These computer tapes contain cartographic data in digital form. They are available in two forms. The graphic form can be used to generate computer-plotted maps. The topologically-structured form is suitable for input to geographic information system for use in spatial analysis and geographic studies.	Tapes are available for the entire US, including Alaska, and Hawaii, and are sold in 4 thematic layers: boundaries, transportation, hydrography and US Public Land Survey System. Each of the four layers can be purchased individually. US Geodata tapes can be ordered through Earth Science Information (ESIC) Center, as well as through the following ESIC offices. Anchorage, AK ESIC - (907) 561-5555/FTS 271-4320, (907) 271-4307/FTS 271-4307; Denver, CO ESIC - (303) 844-4169/FTS 564-7169, (303) 236-5829/FTS 776-5829; Los Angeles, CA ESIC - (213) 894-2850/FTS 798-2850; Menlo Park, CA ESIC - (415) 329-4390/FTS 459-4390; Reston, VA ESIC - (703) 860-6045/FTS 959-6045; Rolla, MO ESIC - (314) 341-0851/FTS 277-0851; Salt Lake City, UT ESIC - (801) 524-5652/FTS 588-5652; San Francisco, CA ESIC - (415) 556-5627/FTS 556-5627; Spokane, WA ESIC - (509) 456-2524/FTS 439-2524; and Stennis Space Center, MS ESIC - (601) 688-3544/FTS 494-3544.
Topographic Maps Users Service Geographic Names Information System (GNIS) EROS Data Center Sioux Falls, SD 57198 (605) 594-6151	Organized and summarized information about cultural or physical geographic entities.	GNIS provides a rapid means of organizing and summarizing current information about cultural or physical geographic name entities. The data base contains a separate file for each state, the District of Columbia, and territories containing all 7.5-min. maps published or planned.
Topography Data National Geophysical Data Center NOAA, Code E/GCI 325 Broadway Boulder, CO 80303 (303) 497-6900	This system contains a variety of topography and terrain data sets available for use in geoscience applications.	The data were obtained from U.S. Government agencies, academic institutions, and private industries. Data coverage is regional to worldwide; data collection methods encompass map digitization to satellite remote sensing.

GEOLOGIC DATA

Source	Information Obtainable	Comments
Geological Reference Sources: A Subject and Regional Bibliography of Publications and Maps in the Geological Sciences, Ward and others (1981)	Bibliographies of geologic information for each State in the U.S. and references general maps and groundwater information for many sites.	Provides a useful starting place for many site assessments. A general section outlines various bibliographic and abstracting services, indexes and catalogs, and other sources of geologic references.
A Guide to Information Sources in Mining, Minerals, and Geosciences, Kaplan (1965)	Describes more than 1,000 organizations in 142 countries. Its listings include name, address, telephone number, cable address, purpose and function, year organized, organizational structure, membership categories, and publication format. Federal and State agencies are listed for the U.S. as well as private scientific organizations, institutes, and associations.	An older useful guide. Part II lists more than 600 worldwide publications and periodicals including indexing and abstracting services, bibliographies, dictionaries, handbooks, journals, source directories, and yearbooks in most fields of geosciences.
Bibliography and Index of Geology	Includes worldwide references and contains listings by author and subject.	This publication is issued monthly and cumulated annually by the American Geological Institute (AGI), and replaces separate indexes published by the U.S. Geological Survey through 1970 (North American references only) and the Geological Society of America until 1969 (references exclusive of North America only). Both publications merged in 1970 and were published by the Geological Society of America through 1978, when AGI continued its publication.
KWIC (Keyword-in-Contents) Index of Rock Mechanics Literature	Engineering geologic and geotechnical references.	The KWIC index is available in two volumes at many earth science libraries (Hoek, 1969; Jenkins and Brown, 1979).
GEODEX Retrieval System with Matching Geotechnical Abstracts GEODEX Inc. P.O. Box 279 Sonoma, CA 95476	Engineering geological and geotechnical references.	The GEODEX is a hierarchically organized system providing easy access to the geotechnical literature and can be used at many university libraries. The GEODEX system can be purchased on a subscription basis.

Source	Information Obtainable	Comments
U.S. Geological Survey Branch of Distribution 604 S. Pickett St. Alexandria, VA 22304	The U.S. Geological Survey (USGS) produces annually a large volume of information in many formats, including maps, reports, circulars, open-file reports, professional papers, bulletins, and many others.	To simplify the dissemination of this information, the USGS has issued a Circular (No. 777) entitled A Guide to Obtaining Information from the USGS (Clarke, et al., 1981).
U.S. Geological Survey Bibliographic References (CITATN) Elizabeth Wingate Publications Geologic Division Office of Energy and Marine Geology USGS U.S. Dept. of Interior Quissett Campus Woods Hole, MA 02543 (508) 548-8700, ext. 289	CITATN contains 5,800 bibliographic references for publications authored by the U.S. Geological Survey.	CITATN calculates statistical information on output, status, and bibliographic searches by author to title and printouts are available.
U.S. Geological Survey Library Database USGS Main Library National Center MS 950 12201 Sunrise Valley Drive Reston, VA 22092 (703) 648-4302	Contains more than 1 million monographs, serials, maps, and microforms covering chemistry, environmental studies, geology, geothermal energy, mineralogy, oceanography, paleontology, physics, planetary geology, remote sensing, soil science, cartography, water resources, and zoology.	This library system is one of the largest earth science libraries in the world. Library staff and users may access the online catalog from terminals at each of the 4 USGS libraries. The data base can be searched by author, title, key words, subjects, call numbers, and corporate/conference names. The Library System staff at all locations will conduct literature searches using various data bases. Computer-related costs are charged if applicable. Regional libraries are located in Denver, CO; Flagstaff, AZ; and Menlo Park, CA. The USGS Library Data base is available on CD-ROM from OCLC, Inc.
Geologic Names of the United States (GEONAMES) Geologic Division USGS 907 National Center Reston, VA 22092	GEONAMES is an annotated index of the formal nomenclature of geologic units of the United States. Data includes distribution, geologic age, USGS usage, lithology, thickness, type locality, and references.	Printouts are not available. Diskettes containing data for 2 or more adjacent states are available from USGS Open-File and Publications, Box 25425 Federal Center, Denver, CO 80225 (303) 235-7476. Magnetic tapes can be obtained from NTIS.

Source	Information Obtainable	Comments
Geologic Names Users Service EROS Data Center Sioux Falls, SD 57198 (605) 594-6151	The rock stratigraphic names in good usage in the United States have been coded by the USGS in accordance with the standard stratigraphic code adopted by the American Association of geologists. Each Contains the state in which the unit occurs, its geologic age, a four-letter mnemonic code of the name, a two-digit sequence number to help identify that record, the geologic name of the unit, lithology, thickness, color, type locality, and reference.	
USDA Soil Conservation Service (202) 447-4525	Soil maps and description are available for about 75% of the country through the U.S. Soil Conservation Service office located in each state capital.	Geology libraries of most universities have these reports available for reference.
California Division of Mines and Geology 801 K Street Sacramento, CA 95814 (916) 327-1850	Publications and maps of the Division of Mines and Geology	The CDMG maintains several libraries and has copies of geologic and geophysical reports and maps available for purchase.
CDMG ON-LINE (916) 327-1208	Bulletin board of the California Division of Mines and Geology	This free bulletin board is open to the public and contains, among other things, indexes to publications of the CDMG and the California Division of Oil and Gas, and a current index of geologic events (earthquakes, landslides, volcanic eruptions, etc.)
California Department of Water Resources Publications Section 1416 9th Street P.O. Box 942836 Sacramento, CA 94236-0001	Publications of the California Department of Water Resources	Hydrologic reports, water-quality reports, engineering, geologic and environmental reports for construction of state water projects, and engineering and geologic reports on dam safety are available for purchase.

GEOPHYSICAL DATA

Source	Information Obtainable	Comments
U.S. Geological Survey Water Supply Papers	The most common types of geophysical data are available from seismic and resistivity surveys.	Water Supply Papers for an area can be located by any of the computer searches or published indexes described in the first section of this paper. In addition, the USGS also publishes geophysical maps of various types at relatively small scales for many areas of the U.S. Aeromagnetic maps have been completed for much of the U.S., although the flight altitude of several thousand meters and scale of 1:24,000 make these maps too general for most site specific work.
Well Log Libraries Electric Log Services P.O. Box 3150 Midland, TX 79702 Tel: (915) 682-0591	Sample and electric logs for many petroleum wells can be obtained from one of several well log libraries in the U.S.	The geophysical logs are indexed by survey section. To obtain information on wells in a given area, it is necessary to compile a list of the townships, ranges, and section numbers covering the area.
Geophysical Survey Firms	Specific geophysical logs	Proprietary geophysical data can sometimes be obtained from private survey firms. In general, the original client should approve the exchange of information, and preference is given for academic purposes. If the information cannot be released, firms may be willing to provide references to published information they obtained before the survey, or information published as a result of the survey.
Geophysical Mapping System (GMS) Users Service EROS Data Center Sioux Falls, SD 57198 (605) 594-6151	Geophysical mapping system (GMS) is a cartographic data base and mapping system for base maps used for lease-tract evaluation for any area.	
Geomagnetism (GEOMAG) Branch of Global Seismology and Geomagnetism USGS Box 25046 Federal Center Mail Stop 968 Denver, CO 80225 (303) 236-1369	GEOMAG contains current and historical magnetic-declination information for the United States. It provides historical and current values of declination.	Current or historical values back to 1945 can be obtained over the telephone at no charge by calling (800) 358-2663. To access the full program via modem, contact the listed office for hook-up instructions. There is no subscription fee.

Source	Information Obtainable	Comments
National Geophysical Data Center (NGSDC) Chief, Solid Earth Geophysics 325 Broadway Boulder, CO 80303 (303) 497-6521 FTS 320-6521	NGSDC maintains a computer file of more than 136,000 seismographs of earthquakes, known or suspected explosions and associated collapse phenomena coal bumps, rockbursts, quarry blasts, and other earth disturbances recorded worldwide starting in January 1900. Historic U.S. earthquakes are included for the period starting in 1638.	Site studies for many projects now require information regarding the seismicity of the region surrounding the site. The National Geophysical and Solar-Terrestrial Data Center (NGSDC) of the National Oceanic and Atmospheric Administration (NOAA) is a focal point for dissemination of earthquake data and information for both technical and general users, except for information on recent earthquakes. (Information about recent earthquakes can be obtained by contacting the USGS.) For a fee, a search can be made for one of the following parameters: -Geographic area (circular or rectangular area) -Time period (staring 1638 for U.S.) -Magnitude range -Date - Time - Depth -Intensity (Modified Mercalli)
California Division of Mines and Geology 801 K Street Sacramento, CA 95814 (916) 327-1850	Publications and maps of the Division of Mines and Geology	The CDMG maintains several libraries and has copies of geologic and geophysical reports and maps available for purchase.
CDMG ON-LINE (916) 327-1208	Bulletin board of the California Division of Mines and Geology	This free bulletin board is open to the public and contains, among other things, indexes to publications of the CDMG and the California Division of Oil and Gas, and a current index of geologic events (earthquakes, landslides, volcanic eruptions, etc.)

REMOTE SENSING

Source	Information Obtainable	Comments
USGS Earth Resources Observation Systems (EROS) Data Center User Service EROS Data Center U.S. Geological Survey Sioux Falls, SD 57198 (605) 594-6151 FTS 784-7151	The EROS Program provides remotely-sensed data. Additional information can be found in the publications <u>The EROS Data Center</u> and <u>The Landsat Data User's Handbook</u>. To obtain these publications, request further information, or place an order, contact the EROS Data Center.	The EROS Data Center, near Sioux Falls, South Dakota, is operated by the EROS program to provide access primarily to NASA's Landsat imagery, aerial photography acquired by the U.S. Department of the Interior, and photography and multi-spectral imagery acquired by NASA from research aircraft, Skylab, Apollo, and Gemini spacecraft. The primary functions of the Data Center are data storage and reproduction, user assistance, and training. The Data Center can provide a computer listing of all imagery on file for three geographic options: 1.Point search - all images or photographs with any portion falling over the specific point of longitude and latitude are included. 2.Area quadrilateral - any area of interest defined by four coordinates of longitude and latitude. All images or photographs with any coverage of the area are included. 3.Map specification - a point or area may be indicated on a map. (Options 1 and 2 are preferred by EROS.)
Aerial Photography Field Office U.S. Department of Agriculture P.O. Box 30010 Salt Lake City, UT 84130 (801) 524-5856 FTS 588-5857	Conventional aerial photography scales of 1:20,000 to 1:40,000.	Aerial photographs by the various agencies of the U.S. Department of Agriculture (Agricultural Stabilization and Conservation Service [ASCS], Soil Conservation Service [SCS], and Forest Service [USFS]) cover much of the U.S.
Photogrammetry Division of NOAA National Oceanic and Atmospheric Administration 6001 Executive Blvd. Rockville, MD 20852 (301) 443-8601 FTS 443-8601	The Coastal Mapping Division of NOAA maintains a file of color and black and white photographs of the tidal zone of the Atlantic, Gulf, and Pacific coasts. The scales of the photographs range from 1:20,000 to 1:60,000.	An index for the collection can be obtained for free by contacting the Coastal Mapping Division at (301) 443-8601 or the address listed.

Source	Information Obtainable	Comments
U.S. Bureau of Land Management Aerial Photo Section Larry Cunningham (SC-675) P.O. Box 25047 Denver, CO 80225-0047 (303) 236-7991	The Bureau of Land Management has aerial photographic coverage of approximately 50 percent of its lands in 11 western states.	For an index of the entire collection contact the U.S. Bureau of Land Management at (303) 236-7991 or the address listed.
Landsat Data	Landsat satellites sensor images are found in spectral bands: -Band 4 (emphasizes sediment-laden and shallow water) -Band 5 (emphasizes cultural features) -Band 6 (emphasizes vegetation, land/water boundaries, and landforms) -Band 7 (as above, with best penetration of haze) -Band 5 gives the best general-purpose view of the earth's surface. Black and white images and false-color composites are available.	The Landsat satellites were designed to orbit the earth about 14 times each day at an altitude of 920 km, obtaining repetitive coverage every 18 days. The primary sensor aboard the satellites is a multi-spectral scanner that acquires parallelogram images 185 km per side in four spectral bands.
NASA Aerial Photography	Photography is available in a wide variety of formats from flight at altitudes ranging from one to 18 km. Photographs generally come as 230 mm by 230 mm prints at scales of 1:60,000 or 1:120,000, and are available as black and white, color, or false-color infrared prints.	NASA aerial photography is directed at testing a variety of remote-sensing instruments and techniques in aerial flights over certain preselected test sites over the continental U.S.

Source	Information Obtainable	Comments
Aerial Mapping Photography	Aerial photography coverage obtained by the USGS and other Federal agencies (other than the Soil Conservation Service) for mapping of the U.S. is available as 230 mm by 230 mm black and white prints which are taken at altitudes of 600 m to 12 km. Scales range from 1:20,000 to 1:60,000.	Because of the large number of individual photographs needed to show a region on the ground, photomosaic indexes are used to identify photographic coverage of a specific area. The Data Center has more than 50,000 such mosaics available for photographic selection.
National Archives and Records Service Cartographic Archives Division General Services Administration 8 Pennsylvania Ave., N.W. Washington, DC 20408 (703) 756-6700	Airphoto coverage obtained before 1942 for portions of the U.S.	This service may be important for early documentation of site activities.
Commercial Aerial Photo Firms American Society for Photogrammetry and Remote Sensing 5410 Grosvenor Lane Suite 210 Bethesda, MD 20814 (301) 493-0290		In many instances, these firms retain the negatives for photographs flown for a variety of clients and readily sell prints to any interested users. For a listing of nearby firms specializing in these services, consult the yellow pages.

HYDROLOGIC DATA

Source	Information Obtainable	Comments
Water Publications of State Agencies, Giefer and Todd (1972, 1976)	This book lists state agencies involved with research related to water and also lists all publications of these agencies. In general, hydrologic data can be classified into four primary categories: stream discharge, stream water quality, groundwater level, and groundwater quality.	The trend for the past decade has been to compile such basic data in computerized data banks, and a number of such information systems are now available for private and public users. Many data now collected by Federal and state water-related agencies are available through computer files, but most data collected by private consultants, local and county agencies, and well drilling contractors remain with the organization that gathered them.
Local Assistance Center of the National Water Data Exchange (NAWDEX) U.S. Geological Survey 421 National Ctr. Reston, VA 22092 (703) 648-5663	NAWDEX identifies organizations that collect water data, offices within these organizations from which the data may be obtained, alternate sources from which an organization's data may be obtained, the geographic areas in which an organization collects data, and the types of data collected. Information has been compiled for more than 600 organizations, and information on other organizations is added continually. More than 300,000 data collection sites are indexed.	NAWDEX, which began operation in 1976 and is administered by the U.S. Geological Survey consists of a computer directory system which locates sources of needed water data. The system helps to link data users to data collectors. For example, the NAWDEX Master Water Data Index can identify the sites at which water data are available in a geographic area, and the Water Data Sources Directory can then identify the names and addresses of organizations from which the data may be obtained. In addition, listings and summary counts of data, references to other water data systems, and bibliographic data services are available.
WATSTORE Branch of Computer Technology USGS Reston, VA 22092 (703) 648-5686	WATSTORE maintains the storage of: 1) surface-water, quality-of-water, and ground-water data measured on a daily or a continuous basis; 2) annual peak values of stream flow stations; 3) chemical analyses for surface- and ground-water sites; 4) water-data parameters measured more frequently than daily; 5) geologic and inventory data for ground-water sites; and 6) summary data on water use.	Data can be retrieved in machine-readable form or as computer printed tables or graphs, statistical analyses, and digital plots.

Source	Information Obtainable	Comments
Published Water-Supply Studies and Data	Stream discharge, groundwater level, and water quality data obtained during short-term, site-specific studies, typically available only in published or unpublished site reports. Data related to lakes, reservoirs, and wetlands are commonly found only in such reports.	Although significant progress has been made in computerizing surface- and groundwater data, the majority remains available only through published and unpublished reports.
Catalog of Information on Water Data	The reference consists of four parts: -Part A: Stream flow and stage -Part B: Quality of surface water -Part C: Quality of groundwater -Part D: Aerial investigations and miscellaneous activities.	Bibliographic publication indexes USGS sampling and measurement sites throughout the U.S. Maps are available that show a distinct numeric code assigned to each river basin and provide information on drainage, culture, hydrography, and hydrologic boundaries for each of the 21 regions and 222 subregions designated by the Water Resources Council. They also depict the boundaries and codes of 352 accounting units within the National Water Data Network and approximately 2,100 cataloging units of survey's Catalog of Information on Water Data.
Geologic and Water-Supply Reports and Maps (available for each state)		This publication lists USGS references for each state or district by report number, requiring a scan of the entire list for information on a particular area.
Water Resources Investigations, by State Office of Water Data U.S. Geological Survey 417 National Ctr. 12201 Sunrise Valley Drive Reston, VA 22092	Listed are all agencies cooperating with the USGS in collecting water data, information on obtaining further information, and a selected list of references by both the USGS and cooperating agencies.	This booklet describes the projects and related publications for all current USGS work in a state or region. Also available is a useful summary folder with the same title that depicts hydrologic-data stations and hydrologic investigations in a district as of the date of publication. Additional assistance can be obtained by contacting: Hydrologic Information Unit, U.S. Geological Survey, 420 National Center, 12201 Sunrise Valley Drive, Reston, VA 22092.
National Stream Quality Accounting Network (NASQAN) USGS Branch of Distribution 1200 South Ends St. Arlington, VA 22202	Regional and nationwide overview of the quality of our streams.	Consists of over 400 sampling sites. Data collection sties are located at or near the downstream end of hydrologic accounting units or at representative sites along coastal areas and Great Lakes.

Source	Information Obtainable	Comments
Federal Flood Insurance Studies	To meet the provisions of the National Flood Insurance Act of 1968, the USGS, with funding by the Federal Insurance Administration, has mapped the 100-year floodplain of most municipal areas at a scale of 1:24,000.	Floodplain maps can be obtained from the nearest district office of the USGS and commonly from other agencies, such as the relevant city, town, or county planning office, or the Federal Insurance Administration. In some areas, more detailed "Flood Insurance Studies" have been completed for the Federal Emergency Management Agency; these maps include 100-year and 500-year floodplain maps. The complete studies are available at the nearest USGS office, the relevant city, town, or county planning office, or the Federal Emergency Management Agency.
Office of Water Data Coordination (OWDC) USGS 417 National Center Reston, VA 22092 (703) 648-5016	Publications including the "National Handbook of Recommended Methods for Water-Data Acquisition," indexes to the "Catalog of Information on Water Data," and other publications.	OWDC is the focal point for inter-agency coordination of current and planned water-data acquisition activities of all Federal agencies and many non-Federal organizations.
National Ground Water Information Center (NWWA) 6375 Riverside Drive Dublin, OH 43017 (800) 242-4965	Computerized, on-line databases, and an electronic bulletin board that provide a variety of information on the quantity and quality of ground-water resources in the United States. Also includes full text on State and Federal ground-water regulations and ground-water public information brochures.	Database and electronic bulletin board are accessible through computer, modem and telecommunications software. Membership is required to gain access. Records are relatively short and non-technical.
California Department of Water Resources Publications Section 1416 9th Street P.O. Box 942836 Sacramento, CA 94236-0001	Publications of the California Department of Water Resources	Hydrologic reports, water-quality reports, engineering, geologic and environmental reports for construction of state water projects, and engineering and geologic reports on dam safety are available for purchase.

CLIMATIC DATA

Source	Information Obtainable	Comments
National Climatic Center (NCC) Federal Building Asheville, NC 28801 (704) 259-0682	Readily available are data from the monthly publication Climatological Data, which reports temperature and precipitation statistics for all monitoring stations in a given state or region. An annual summary is also available.	The National Climatic Center (NCC) collects and catalogs nearly all U.S. weather records. Climatic data (which are essential for construction planning, environmental assessments, and conducting surface and groundwater modeling) can be obtained from the NCC.
	In addition to collecting basic data, NCC provides the following services: -Supply of publications, reference manuals, catalog of holdings, and data report atlases -Data and map reproduction in various forms -Analysis and preparation of statistical summaries -Evaluation of data records for specific analytical requirements -Library search for bibliographic references, abstracts, and documents -Referral to organizations holding requested information -Provision of general atmospheric sciences information.	NCC can provide data on file in hard (paper) copy, in microfiche, or on magnetic tape. For general summary statistics and maps, the publication Climates of the States - NOAA Narrative Summaries, Tables, and Maps for Each State, by Gale Research Company (1980) is helpful.

Reference: USEPA, 1991, Test methods for evaluating solid waste, physical/chemical methods, United States Environmental Protection Agency, Office of Solid Waste, SW-846, Appendix 4.

8. REFERENCES

Cal EPA, 1995a, Guidelines for hydrogeologic characterization of hazardous substance release sites, volume 1: field investigation manual, California Environmental Protection Agency, Department of Toxic Substances Control.

Cal EPA, 1995b, Application of surface geophysics at hazardous substance release sites, California Environmental Protection Agency, Department of Toxic Substances Control, 19 p.

Cal EPA, 1995c, Drilling, coring, sampling and logging at hazardous substance release sites, California Environmental Protection Agency, Department of Toxic Substances Control, 27 p.

Cal EPA, 1995d, Application of borehole geophysics at hazardous substance release sites, California Environmental Protection Agency, Department of Toxic Substances Control, 23 p.

Cal EPA, 1995e, Monitoring well design and construction for hydrogeologic characterization, California Environmental Protection Agency, Department of Toxic Substances Control, 43 p.

Cal EPA, 1995f, Representative sampling of ground water for hazardous substances, California Environmental Protection Agency, Department of Toxic Substances Control, 34 p.

Cal EPA, 1995g, Aquifer testing for hydrogeologic characterization, California Environmental Protection Agency, Department of Toxic Substances Control, 29 p.

Cal EPA, 1995h, Ground water modeling for hydrogeologic characterization, California Environmental Protection Agency, Department of Toxic Substances Control, 17 p.

Cal EPA, 1995i, Reporting hydrogeologic characterization data from hazardous substance release sites, California Environmental Protection Agency, Department of Toxic Substances Control, 14 p.

CBCEC, 1993, Recommended content and presentation for reporting hydrogeologic data during site investigations, California Base Closure Environmental Committee, p. 2.

DTSC, 1993, Imminent and/or substantial endangerment policy, procedure and guidelines, California Environmental Protection Agency, Department of Toxic Substances Control, EO-93-009-PP, 74 p.

DTSC, 1994, Preliminary endangerment assessment guidance manual, California Environmental Protection Agency, Department of Toxic Substances Control.

Javandel, I., C. Doughty and C.F. Tsang, 1984, Groundwater transport: handbook of mathematical models, American Geophysical Union, Water Resources Monograph 10, p. 1.

USEPA, 1986, Superfund public health evaluation manual, United States Environmental Protection Agency, Office of Emergency and Remedial Response, EPA/540/1-86/060 (OSWER Directive 9285.4-1), p. 14-26.

USEPA, 1987, A compendium of superfund field operations methods, United States Environmental Protection Agency, Office of Emergency and Remedial Response, EPA/540/P-87/001 (OSWER Directive 9355.0-14), p. 8.1-1 to 9-48.

USEPA, 1988, Guidance for conducting remedial investigations and feasibility studies under CERCLA, United States Environmental Protection Agency, Office of Emergency and Remedial Response, EPA/540/G-89/004 (OSWER Directive 9355.3-01).

USEPA, 1991, Test methods for evaluating solid waste, physical/chemical methods, United States Environmental Protection Agency, Office of Solid Waste, SW-846, p. Eleven-158.

USEPA, 1993, Guidance on conducting non-time-critical removal actions under CERCLA, United States Environmental Protection Agency, Office of Solid Waste and Emergency Response, EPA540-R-93-057, 57 p.

INDEX